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MAIN PRINCIPLES OF STRATIGRAPHIC DIVISION OF THE QUATERNARY SYSTEM AND LOCATION OF ITS LOWER BOUNDARY[1]

by

V. I. Gromov, I. I. Krasnov and K. V. Nikiforova

The study and the mapping of Quaternary posits is of great scientific and practical portance. A major quantity of factual aterial on stratigraphy, paleontology, and chaeology of the Quaternary of the glacial d periglacial regions of the earth has en collected in recent years.

New general concepts of universal impor-nce are outlined in this paper. Many funda-ental problems of Quaternary geology were lved in preceding international geologic nventions and Quaternary conferences. The ost recently accepted decisions on the atigraphic division of the Quaternary stem and the principles of legend compila-n for the Quaternary map were accepted 1932 at the Second International Conven-n of the Association for the Study of the aternary System in Europe, which took ice in Leningrad.

The material accumulated since that ne indicates the need for further correla-n and acceptance of basic concepts on atigraphy and the method of mapping the aternary system. Much material is al-ady compiled and prepared by the scien-ts of different countries, but a lack of derstanding somehow retards new Quater-ry studies. As recently as 1948, in the III Session of the International Geological ngress in London, propositions were ered on the necessity of lowering the undary of the Quaternary system; twenty-papers were devoted to this problem. is problem was also broadly discussed at following XIX Session of the International ological Congress (Algiers, 1952), at an ernational conference (INQUA) in 1954 in me, in a geologic conference of the untries of the people's democracies in rsaw, and also in the Soviet Union in erdepartmental conferences, and at the All-Union Conference in Moscow in 1957, at which the representatives of the Chinese National Republic, German Democratic Republic, Czechoslavakian, Hungarian, Rumanian and Polish National Republics were also present. Therefore, the necessity of lowering the boundary for the Quaternary system has already been widely discussed.

Also of importance is the determination of the accuracy of the name Quaternary, a problem resulting from the lowering of the system's border. This problem has also been discussed several times in geologic literature.

The conversion of existing stratigraphic subdivisions of the Quaternary system into stages and formations is also a very important problem, because the existing subdivision of the Quaternary system does not correspond in volume with the volumes of the stages and formations of other systems. It is necessary to organize the stratigraphic nomenclature and the system of indexing in a unified stratigraphic column for the system. Finally, due to the recent extensive exploration work it is necessary to detail, to organize, and to confirm the conventional symbols for maps of Quaternary deposits. The same problem should be solved internationally because, we think, the work of compiling an international Quaternary map should be started.

Concrete propositions on the above-mentioned problems were offered for discussion in the Fifth Congress by the authors of this paper.

During the discussion of all these problems in the All-Union Quaternary Convention in May 1957, no unanimous opinion on this series of problems was reached, and in the present article the authors express their own personal point of view, but one which is supported by many Soviet Quaternary geologists.

Paper presented at the Fifth Congress of the ernational Association for the Study of the aternary Period. Madrid, September 1957.

I. Lowering the Boundary of the Quaternary System

The boundary between the Tertiary and Quaternary systems is one of the fundamental stratigraphic divisions in the unified international stratigraphic column and the possibility of tracing it across the vast spaces of continent should be determined. Therefore, the chief criterion for its determination, as it was in determination of the boundaries for other geologic systems, should be biostratigraphic criteria. Paleoclimatic (glacial) criteria are auxiliary ones but they acquire great significance during the separation of the small taxonomic stratigraphic subdivisions, first of all, in regions subjected to glaciation or directly adjoining such regions (periglacial regions).

Contrary to the predominantly marine deposits of the other system, the Quaternary sediments are represented chiefly by continental formations, and due to that fact the detailed study of continental deposits should be the basis for determination of the lower boundary of the Quaternary period.

The continental fauna and flora are therefore of main significance in outlining of the borders of the Quaternary system and its chief subdivisions. The history of Quaternary continental and marine molluscs cannot yet be built on a phylogenetic basis, and they cannot be the basis for stratigraphic subdivision of Quaternary deposits.

The only group of animals whose history at the present level of knowledge can be understood on the basis of phylogenesis, by accounting for migration and geographic zonality, are the mammals. They should be, therefore, a fundamental criterion for outlining stratigraphic borders for the main subdivisions of the Quaternary system.

No less important criteria are the flora and archaeologic remnants (settlements) of the stone age, a very important element of stratigraphy, the same as the remains of the first fossil man and his ancestors.

Biostratigraphic data in the European and Asiatic part of the Soviet Union, in China and western Europe (mammalian fauna, flora, and man) show that the previously accepted position of the lower boundary of the Quaternary system over the Apsheron in U. S. S. R. and Villa Franca layers in western Europe, and over the Ni-Kvang layers in China) is incorrect and requires considerable revision.

As the result of long and systematic investigations of the mammal fauna in the U. S. S. R., B. I. Gromov managed to outline a feasible boundary between the Pliocene and Quaternary systems based on changes in faunal complexes.

In that time, the entire history of the Quaternary fauna, still accepted for the Quaternary period by many scientists, is only the history of subspecies of certain species from the moment of their appearance, i. e., only an insignificant interval in the history of development of the contemporary fauna, and, therefore not adequate for establishing the boundary between the systems. Those faunal appearances are sufficient only for outlining the stratigraphic boundaries between formations and series, i. e., within the system. The history of genera, let alone families, cannot be traced in such a short period of time, because their development started considerably earlier -- in the Pliocene. By the Late Pliocene, together with the mastadon (Anancus avernensis) and rare remnants of hipparion, we find a great number of genera which are the ancestors of the contemporary mammals: Equus, Elephas, Bos, Camelus, Rhinoceros, Canis, Lepus (Khaprov Faunal Complex). In the same interval of time (the end of the Middle and the beginning of the Late Pliocene) the most ancient direct ancestors of the Hominidae family (Plesianthropus, Paranthropus, Altanthropus) appeared.

Hence, the history of the modern fauna, from the advent of certain families and subfamilies, genera with sub-genera and species with sub-species, and, finally, the whole story of man, from his direct ancestors, embraces a considerably greater interval of time than the Quaternary period in its contemporary definition, i. e., it should include all time since the end of the Middle Pliocene to the Holocene, but the Quaternary period as presently conceived, encompasses only part of this time, and, therefore, only represents the last geologic period during which very important events occurred in the history of the Earth.

Analysis of plant fossils from Cenozoic deposits in the U. S. S. R., according to V. P. Grichuk, indicates several sharp changes in the development of the Cenozoic flora. The last discontinuity is related to the transition from the Kimmerian formation to the Akchagyl' formation, when in the widespread holarctic genera prevailed due to changes in climate. After this, only very gradual changes in flora, e. g., disappearance of thermophilous plants, took place.

All this data on flora, fauna and ancestors of man permits us to set the lower boundary of the Quaternary period in the U. S. S. R. in its extra-glacial European part below the Upper Pliocene, i. e., under

haprovsk and Yergeninsk deposits, and nder the Akchagyl (?); in glacial regions nder deposits of the so-called Oka glacia-on.

In the Asiatic part of the U. S. S. R., west f the Yenisey River, this boundary in xtra-glacial regions situated under deposits ith remnants of Equus stenosis and Anancus vernensis (Overnian mastodon) usually ccurs at the upper terraces of contempo-ry valleys with red alluvial beds.

In Eastern Siberia (Trans-Yenisey part) e lowest deposits of the Quaternary system e still unknown. The oldest are the depos-s containing remnants of mammals of the ldan fauna, correlative with the Taman' unal complex of the European U. S. S. R., with the fauna of the Upper Ni-he-vang posits in China, with which it has some mmon elements.

In western Europe, therefore, this boun-ry will go in extra-glacial regions under e Villa Franca continental and equivalent labrian marine layers, and in glacial gions under the deposits of the so-called nubian (or Guentz) Alp glaciation or roslavl' glaciation (Poland), i. e., as commended in the XVIII Session of the ternational Geological Congress. In China, is boundary is set under the Ni-he-vang posits (lower San-Ming), and in Africa der the Cager layers.

The necessity of lowering the boundary the Quaternary system stems not only m analysis of biostratigraphic data, but so from analysis of paleoclimatic mate-l, in particular, from the epoch of the eat continental glaciations. Glaciations e considered to be one of the basic dis-guishing features of the Quaternary stem; in the meantime, the lower boun-ry at present is outlined so that one and ssibly several of the most ancient glacia-ns occurred in the Late Pliocene, which illogical. It is expedient to include in e Quaternary system not only all glacial ochs, but also the entire, long preglacial riod characterized by gradual cooling.

The beginning of this very important leoclimatic interval coincides with the ginning of the Late Pliocene. Therefore, e paleoclimatic indices can serve as the sis for the lowering of the system's undary. It has also been confirmed by ta on paleogeography of the glacial gions of the European part of the U.S.S.R. .I. Moskvitin, 1956, 1957; S.A. Yakov-, 1956).

Analysis of neotectonics and the history development of the main features of modern relief also confirm the necessity of more or less considerably lowering the lower boundary of the Quaternary period. N.I. Nikolayev in the XIX Session of the International Geological Congress in Algiers (1952) devoted a special lecture to this subject.

In decisions of the All-Union Conference in May 1957, it was written: "The majority of the participants of the conference consider that there are sufficient grounds to consider the question of lowering the presently accepted boundary for the Quaternary system. However, until this problem is specifically solved and ratified by the International Stratigraphic Committee it is advisable to keep the presently accepted boundary." All points of view on the necessity of lowering the boundary of the Quaternary system in western Europe, Africa, South and North America were discussed by V.I. Gromov (1950) and A.I. Moskvitin (1957) and included in their abstracts of foreign literature on the lowering of the boundary of the Pleistocene. These conclusions coincide completely with our conception of the lower boundary of the Quaternary system, and, therefore, we will not repeat them in the present paper. Besides, these points of view are given in the papers of international conferences and are well known to foreign scientists.

Taking into consideration the recommendation of the XVII and XIX Sessions of the International Geological Congress, international Quaternary conferences, and the All-Union Conference, the authors of this paper consider that this problem is sufficiently clear. It is evident, that justification of the position of the lower stratigraphic boundary of the Quaternary system is based on study, chiefly of continental deposits, which is correct as noted above; however, until recently, the necessary correlation of continental deposits and marine sediments was not made. This should be the subject of further investigations.

II. Changing of the name of the Quaternary system

As the result of the lowering of the boundary of the Quaternary system to include the Upper Pliocene, the total duration of the Quaternary period becomes almost 5 times (from 600 to 800 thousand years to 3.5 to 4.0 million years) longer. Correspondingly, the make-up of the system is changed, the number of geologic events taking place in this greater period of time is considerably increased, and therefore the suggestion of several scientists on the need for changing the name "Quaternary period" should be considered. A possible objection against a

new name, i.e., the priority of the old name, we think, has no grounds, because the volume and content (hence, the time it represents) of this system is changed.

Because at the threshold of this new system, an event of extreme importance occurred -- the direct ancestors of man appeared and evolved from the most ancient representatives of Hominidae to contemporary Homo sapiens -- it would be quite correct to give to this period the new name "Anthropogenic period," i.e., period of appearance and development of man, instead of the obsolete name "Quaternary period"; this name was offered as long ago as 1922 by academician A.P. Pavlov. This name was later supported by several Soviet scientists: A.N. Mazarovich (1945), N.E. Nikolayev (1947), V.I. Gromov (1947) and also by Polish scientists.

Separation of the Anthropogenic period in the history of the Earth would bring a basic consistency to this geologic subdivision.

Among the decisions of the All-Union Conference in 1957 was the following: "The majority of participants of the conference support the proposition on utilization of the term "Anthropogenic," together with the old term "Quaternary period." At the coming conference this problem should also be solved.

III. Changing the Nomenclature of Stratigraphic Subdivisions

Lowering the boundary of the Quaternary (Anthropogenic) system results in the necessity of changing its stratigraphic subdivisions. It was noted above that the existing scheme of stratigraphic subdivision of the Quaternary system into four series is not perfect because these subdivisions do not correspond to the meaning of series in the unified stratigraphic column.

The reason for this inconsistency is, as noted in 1932, that during the study of the principles of stratigraphic division of the Quaternary system for the legend of the international map of Quaternary deposits of Europe, a proposition was made to divide the system into four parts. Those parts were then called series and this would initiate the further division of the series into formations. As the result of the application of a basically incorrect scale, the investigators are now distinguishing in their stratigraphic schemes, as many as 16 formations.

Evidently, in the Quaternary system, the duration of which even within new boundaries would be five to six times smaller than other systems, there should not be such a great number of formations.

Because, at the present time, the method of simultaneous mapping of Quaternary and pre-Quaternary formations is widely used, a need for outlining the unit stratigraphic nomenclature arises. This will permit separation of equivalent formations according to taxonometric importance on geologic maps and legends and would systematize the stratigraphic nomenclature of the Quaternary system; and this will give the advantage of equivalence of this scale with the scale used for other systems in complex geologic mapping.

The single stratigraphic column has been worked out on the basis of decisions and orders of International Geological Congresses. In the U.S.S.R. it was accepted by the All-Union Interdepartmental Stratigraphic Committee in 1955.

The single stratigraphic column is already developed in the U.S.S.R. up to six categories, i.e., the following interdependent units have been established: 1 - group, 2 - system, 3 - series, 4 - formation, 5 - zone, 6 - stratum.

Besides the basic subdivisions listed, the use of subdivisions of intermediate importance with the use of prefix "over" for larger units and the prefix "sub" for units smaller than the given units has been recommended (e.g., subformation, subzone, etc.). Based on the definition of criteria for the separation of stratigraphic subdivisions corresponding to the single stratigraphic column, we are proposing to divide the Quaternary (Anthropogene) system in its new, widened sense, i.e., with lowered boundary, into three series: Eopleistocene, Pleistocene, Holocene, i.e., into categories of the third order. It is necessary to include in the Pleistocene, as suggested by V.I. Gromov (1957), the entire Upper Pliocene, and also the entire Eopleistocene (Lower Pleistocene) of the 1932 scheme of the International Quaternary Commission of Europe. The criteria for separation of the Eopleistocene are, together with relics of hipparion fauna (characteristic of the Upper Neogene), the appearance of all basic elements of the contemporary animal and plant world and also the noticeable change of climate toward lower temperatures in comparison to the climatic maximum of the Neogene. This cooling, according to some investigators, brought about one or several glaciations already in Eopleistocene time.

The wide distribution in the Eopleistocene of redbed sediments is also noted. In the

entire territory of the U.S.S.R. in this period of time, extensive savanah-type areas prevailed, and the appearance of the direct ancestors of man occurred in South Asia and Africa.

The border between the Eopleistocene and Pleistocene should be outlined under the sediments directly preceding the maximum (Dnieper) glaciation, i.e., the Mindel-Riss of the Alpian scheme. In extraglacial regions this boundary will go under sediments characterized by the Khazar faunal complex.

We propose to include in the Pleistocene all time during which extensive continental glaciation occurred. In the organic world, the total disappearance of Tertiary relics is noted. The cold-loving fauna and flora of modern type was more widely distributed than at present. The disruption of continuous areas took place. The evolution of man's ancestors from Pithecanthropus, Sinanthropus, and Neanderthalensis, to the man of contemporary type, was completed at the end of maximum glaciation. Pleistocene sediments of the huge territories of Eurasia are characterized by prevalence of brown and grey shades in contrast to the red-colored Eopleistocene beds.

The border between the Pleistocene and Holocene is connected with general changes in climate toward higher temperatures and considerable erosion of features of the last glaciation. In Central Europe, the formation of river valleys occurred during this time. In the organic world, an extinction of such typically glacial faunal representatives as the mammoth and woolly rhinoceros took place; the formation of contemporary biocoenoses was completed; a neolithic culture appeared.

Therefore, the beginning of the Holocene coincided with the termination of the last glaciation of Fennoscandia (Sal'pausel'ka) and the end of Sartan mountain valley glaciation in the Asian part of the U.S.S.R. In North America, the border of the Holocene is related to the end of the last glaciation (above the Mankato stage). We propose to include all formations originating in the last 10,000 to 12,000 years (absolute age) in the Holocene. This period is characterized by the presence of modern biocoenoses, development of the material culture of man, from Neolithic time to the present, wide migration of contemporary human races, and completion of formation of modern geographic landscapes.

Regardless of the small duration of the Holocene, we are considering its separation into an independent series because of the several qualitative differences, mentioned above, from the preceding Pleistocene. Besides, it is necessary to consider the Holocene as only the beginning of the last series of the Quaternary system which is still not completed and will continue for a long period of time.

The establishment within the system of large stratigraphic subdivisions such as series and formations is based on world-wide geologic events; however, these events in different parts of the Earth were substantially different depending on geography. Regardless of this fact, the boundaries of this stratigraphic subdivision should retain the same name and should be established within the limits of a definite region based on the most typical events.

The Eopleistocene and Pleistocene are divided into formations. The Holocene, because of its brevity and incomplete series of Quaternary sediments, is impossible to divide into formations.

The formation, i.e., a category of the fourth order, we consider as part of a series. The volume and the boundaries of formations are determined from the geologic and paleontologic symptoms reflecting a corresponding stage in the development of the Earth and its organic inhabitants. Formations are characterized by a leading complex of fossil organisms with the characteristics of subfamilies and groups of species belonging to them. Usually, formations have world-wide distribution.

According to the rules of stratigraphic nomenclature, formations receive their own geographic names.

In our paper, the formations still do not have these names and appear as parts of series, e.g., Lower, Middle, and Upper. It is desirable, at the coming conference, to devise geographic names for formations which will be expedient to accept. We propose to consider the priority of existing names and investigators. We propose the following names for the three formations of the Eopleistocene, starting from the bottom: Villafranc, Taman, Tiraspol (or Mindel); for the two formations of the Pleistocene: Riss and Wurn.

The closest correspondence to the formation-size unit in the Quaternary system are found in the subdivisions established by V.I. Gromov, to which are related definite and distinct faunal complexes. Separate formations include several glaciations and interglaciations.

In the Eopleistocene (Q_1), therefore, three formations are distinguished: Lower (Q_1^1) characterized by the Khaprov faunal complex with Elephas planifrons, Equus stenonis,

Hipparion sp., Anancus arvernensis, and also by the remnants of early Prechellian culture of man. It corresponds to Akchagyl and Villafranc formations and also the Preguntzian (Danubian stages) of Alpine glaciation. The middle formation of the Eopleistocene (Q_1^2) is characterized by the Taman faunal complex with Elephas meridionalis, Equus sussenbornensis, and also by remnants of Late Prechellian and Early Chellian culture. The Guntzian glaciation of the Alps and Apsheron formation are of this age.

The upper formation of the Eopleistocene ($Q_1 3$) include the Tiraspol' faunal complex with Elephas wusti, Equus mosbachensis, Bison schoetensacki, Alces latifrons and remnants of the Late Chellian and Early Achellian cultures. The Mindel glaciation of the Alps and Gunz-Mindel interglaciation are related to the Upper formation of the Eopleistocene.

The Pleistocene (Q_2) is divided into two formations: Lower (Q_2^1) characterized by two faunal complexes. Ancient, Khazar complex, corresponding to the time before maximum glaciation, is represented by such forms as Elephas trogontherii, Equus caballus chosaricus, Bison priscus longicornis, Rhinoceros mercki, Ursus spelaeus and the remnants of Late Mouster and Aurignac cultures.

Upper formations of the Pleistocene (Q_2^2) contain an Upper Paleolithic faunal complex with Elephas primigenius (late type), Equus caballus latipes, Bison priscus deminutus, Vulpes lagopus, Rangifer tarandus, Saiga tatarica, Dicrostonyx torquatus, and also archeologic remnants of the Solutrian (mixed fauna), Madlenian (cold fauna), and Asilian cultures. The upper series of the Pleistocene is correlated with Wurmian and Valdaian glaciations and interglaciation preceding them.

Therefore, the formation is the smallest unit of world-wide character which can be separated on general geologic maps. All fractional subdivisions, i.e., orders of the fifth category and lower, are units of regional importance and could be correlated across different countries by different characteristics, mainly by absolute age.

The Holocene (Q_3) is not subdivided into formations; only smaller stratigraphic subdivisions can be established in the Holocene.

Therefore, the formation, i.e., the category of the fourth order, we believe represents a higher taxonomic stratigraphic category than the ages established by many investigators to correspond with separate glaciations and interglaciations.

More fractional stratigraphic divisions are often necessary for the needs of contemporary geologic mapping, carried out at detailed scales, usually 1:200,000 and larger. Actually, such large subdivisions as series and formations already cannot satisfy the requirements of practice.

It is necessary to work over and accept distinct definitions for more small segments of the stratigraphic scale, for example, subformation, zone, subzone, strata, stage, etc. The new scheme permits a taxonomic classification several degrees lower than the existing subdivisions and coordinates the stratigraphy of the Quaternary system with the single unified stratigraphic scale and permits a more systematic classification and indexing of the Quaternary system.

Fractional stratigraphic subdivisions, i.e., fifth and lower taxonomic categories, are established on the basis of paleoclimatic criteria, in particular by lithologic facies, paleontologic (endemic) characteristics, and local ecologic changes.

We propose to discuss the following scheme of stratigraphic subdivision for taxonomic categories lower than formation. The subformation (phase of formation), i.e., category of the fifth order, may represent one glaciation with the preceding interglacial time. Such a subdivision can be useful not only for the glacial regions but also for extraglacial regions where it is impossible to separate smaller subdivisions.

Criteria for separation of subdivisions should be paleoclimatic factors, in particular, the full paleoclimatic cycle: From the beginning of one cooling or warming to the beginning of the next corresponding cooling or warming.

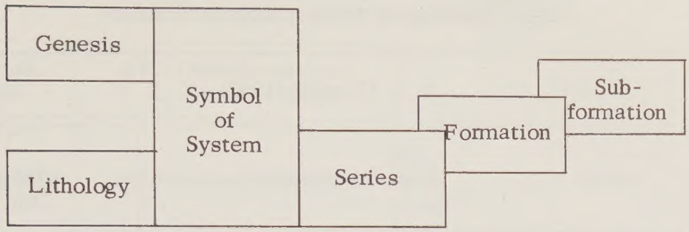
Separation of the fifth category, i.e., subformations, permits lowering the importance of separate glacial and interglacial "epochs" again by one taxonomic category.

The sixth category may represent one entire glaciation or separate interglaciation with a duration of ten thousand years. This subdivision, although still regional, would be, nevertheless, extensive and would be established in glacial and interglacial regions but would not have world-wide distribution, and, therefore, would belong more to the local stratigraphic scale. The term zone can be offered for it. Zones should have a geographic name and a lithologic name, for example: Dnieper, Samara, Moscow, Taz, Odenets, Likhvinsk, Mginsk, Riss-I, Riss-II, Wurm-I, Wurm-II, etc.

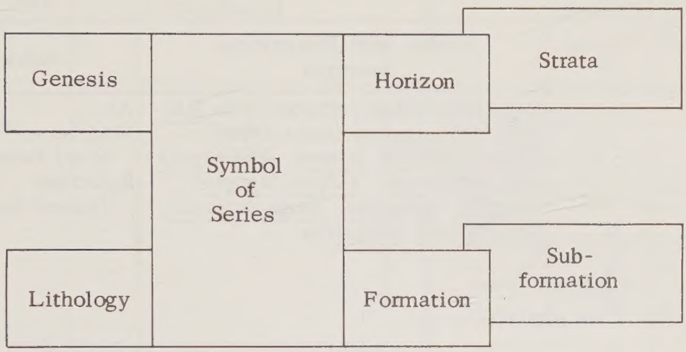
The seventh category should represent the glacial stages and interstages having

Table 1

1. For general geologic maps
(accepted at the Warsaw Conference, 1956).



2. For the special Quaternary map.



more narrow, local importance than categories of the sixth order. They are established, as zones, on the basis of paleoclimatic criteria. The seventh category should include genetically similar formations, which do not distinguish upper or lower, typically interglacial sediments, and therefore represent one glacial unit corresponding to an interglacial stage. As an example we can mention the glacial stages: Vyshne-Volotsk, Astashkovsk, Valday, Luzha, Glyuch, Cander, Frankfurt, Brandewburg, and others.

The duration of the stage is counted in units of thousands of years and is characterized by relatively short-lasting climatic fluctuations. The term "stage" is appropriate for the seventh category. It is good also for periglacial regions, because it reflects the climatic fluctuations which are expressed over considerable territory.

Shorter geologic events, whose duration is counted by a few hundred years, such as oscillation of glaciers of the Salpauselka-type, or similarly important climatic "intervals" of the Holocene evidently belong to a lower, i.e., eighth, taxonomic category.

Finally, formations and geologic events which represent rhythmicity of climatic fluctuation taking place at intervals of 1 to 100 years are necessarily in the lowest stratigraphic category: centennial or seasonal strata.

The necessity for putting in order the existing system of indexing would arise from this new scheme of stratigraphic nomenclature.

We consider that in Quaternary geology the same rules of stratigraphic classification, terminology, and indexing obligatory for all pre-Quaternary systems (see Table 1-1) be accepted.

For special stratigraphic or genetic maps of Quaternary deposits it is necessary to approve more fractional stages of genetic subdivision than were accepted in 1932 for the international map of Quaternary deposits of Europe; the corresponding colors and symbols for their designation should be chosen. A variant of the new legend for genetic symbols appears in Table 1-2.

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Table 2

A Suggested Subdivision and Correlation
of the Quaternary (Anthropogene) System

V. I. Gromov (1957)					
	subdivisions	stages	fauna (mammalian)	archaeology and man	
Quaternary Q (Anthropogene Ag) Period	Q (Holocene) epipleistocene	Upper Q	Recent	Neolithic, Bronze Age, etc.	
		Lower Q	Recent with Pleistocene vestiges	Tardenoise	
	Pleistocene Q	Upper Q	Late Paleolithic complex with Elephas primigenius (later type), Equus caballus latipes, Bison priscus deminutus, Vulpes lagopus, Rangifer tarandus, Saiga tatarica, Dycrostonix torquatus	Az Madeleine (cold fauna) Solutrian (mixed fauna)	Homo neanderthalensis Homo sapiens
		Lower Q	Late Paleolithic complex with Elephas primigenius (earlier type) Rhinoceros antiquitatis Equus caballus latipes (?), Bison priscus deminutus, Elephas primigenius (early type)	Aurignacian (cold fauna) Moustier (later) Moustier (earlier)	
			Khazar complex with Elephas trogontherii, Equus caballus chozaricus, Bison priscus longicornis, Camelus knoblochi, Rhinoceros mercki	Ashell	
	Eopleistocene Q	Upper Q	Tiraspol' complex with Elephas wüsti, Equus mosbachensis, Bison schoentansacki	Ashell Shell (later)	Sinanthropus
		Middle Q	Taman' complex with Elephas meridionalis, Equus sussenbornensis Leptobos, Elasmotherium caucasicum	Shell (earlier) Pre-shell culture	Pithecanthropus
		Lower Q	Khaprov complex with Elephas planifrons, Equus stenonis Hipparion sp., Anancus arvernensis Camelus allutensis and others.	Pre-shell culture	
	Pliocene				

Table 2 (Cont'd)

A Suggested Subdivision and Correlation of the Quaternary (Anthropogene) System

G.F. Mirchink (1933-1939)		I.P. Gerasimov and K.K. Markov (1939)	S.A. Yakovlev (1950)	
subdivisions	stages	subdivisions (epochs)	subdivisions	
Holocene or Recent		Postglacial	Recent	Postglacial (IV)
Late Pleistocene	Würm	Valday glacial	Late Quaternary (III)	Postglacial (III - IV)
				Late glacial 4 (III)
				Late interglacial 4 (III - III)
				Late glacial 3 (III)
				Late interglacial 3 (III - III)
				Late glacial 2 (III)
	Riss-Würm	Last interglacial		Late interglacial 2 (III - III)
Middle Pleistocene	Riss	Moscow stage glacial		Late glacial 1 (III)
		Dnepr glacial		Late interglacial (II - III)
			Mid-Quaternary (II)	Mid-glacial (II)
	Mindel-Riss	Penultimate interglacial		Mid-interglacial (I - II)
Early Pleistocene	Mindel Glaciation	Likhvinian glacial	Early Quaternary (I)	Early glacial 2 (II)
	pre-Mindel			Early interglacial (I - I)
Late Pliocene	Apsheron			Earliest glacial I (I) Pre-glacial (I_0)
	Akchagyl		Late Pliocene	Akchagyl

Table 2 (Cont'd)

A Suggested Subdivision and Correlation
of the Quaternary (Anthropogene) System

<table>
<tr><th colspan="3">A.I. Moskvitin (1956)</th><th colspan="3">F. Ye. Zeiner (1953)</th></tr>
<tr><th></th><th colspan="2">stages (ages)</th><th colspan="2">period</th><th>stratigraphic subdivisions</th></tr>
<tr><td>Recent (holocene)</td><td colspan="2">Holocene</td><td colspan="2">Holocene</td><td>Postglacial</td></tr>
<tr><td rowspan="4">Würms of Late (Neopleistocene)</td><td colspan="2">Ostashkov (glacial)</td><td rowspan="12">Pleistocene</td><td rowspan="4">Late</td><td rowspan="3">Last glaciation</td></tr>
<tr><td colspan="2">Mologo-sheksnin (interglacial)</td></tr>
<tr><td colspan="2">Kalinin (glacial)</td></tr>
<tr><td colspan="2">Mikulin (interglacial)</td><td>Interglacial</td></tr>
<tr><td rowspan="4">Riss or Middle (Mesopleistocene)</td><td colspan="2">Moscow (glacial)</td><td rowspan="4">Middle</td><td rowspan="3">Penultimate glaciation</td></tr>
<tr><td colspan="2">Odintsov (interglacial)</td></tr>
<tr><td colspan="2">Dnepr (glacial)</td></tr>
<tr><td colspan="2">Likhvinian (inter-glacial)</td><td>Penultimate interglacial</td></tr>
<tr><td rowspan="4">Eopleistocene</td><td>Apsheron (Late Mindel) glaciation</td><td>Apsheron transgressions</td><td rowspan="4">Early</td><td>Prepenultimate glaciation</td></tr>
<tr><td colspan="2">Pre-Apsheron "Sandomir" interglacial</td><td>Prepenultimate interglacial</td></tr>
<tr><td rowspan="2">Akchagyl (Ochs) glaciation</td><td rowspan="2">Akchagyl transgressions</td><td>Earliest glaciation</td></tr>
<tr><td>Villefranchian</td></tr>
</table>

Table 2 (Cont'd)

A Suggested Subdivision and Correlation of the Quaternary (Anthropogene) System

	Alps		Northern part of Western Europe (Germany, Poland, Northern France)	
index	After A. Penck, Bruckner, Gramann, Zeiner, Osborn, Shafer, Flint, etc.			
Lgl	Postglacial		Postglacial	
Lgl	One of the stages in the mountains		Fenno-scandinavian moraines	Wechsel
Lgl	Würm 3		Pomeranian moraines	
Lgl	Interstage		Masurian interstage	
Lgl	Würm 2		a) Frankfurt stage b) Brandenburg stage	
Lgl	Interstage		Flemming or Warta	
Lgl	Würm 1			
Llgl	Riss-Würm interglacial		Eems transgression Mauer and Ricksdorff (?)	
Pgl	Riss 2		Saal glaciation (Warsaw I)	
Pgl	Interstage			
Pgl	Riss 1			
PI1	Interstage	Mindel-Riss	Great interglacial (Mazovets I)	
	Glütsch glaciation			
	Interstage			
	Kander glaciation			
	Interstage			
Apgl	Mindel 2		Ulster glaciation (Cracow)	
Apgl	Interstage			
Apgl	Mindel 1			
ApJgl	Günz-Mindel interglacial	Villefranchian		
Egl	Günz 2			
Egl	Interstage ?		Yaroslav glaciation (?) (sharp drop in temperatures)	
Egl	Günz 1			
	Danubian stages Earliest phases			

Table 2 (Cont'd)

A Suggested Subdivision and Correlation of the Quaternary (Anthropogene) System

Paleolithic of Western Europe and man		North America	
After A. Penck, Bruckner, Gramann, Zeiner, Osborn, Shafer, Flint, etc.			
Neolithic	Derivatives and hybrids stemming from Late Paleolithic Homo sapiens	Postglacial	
Mesolithic Pre-Tardenoise Late Madeleine		Two Creeks	Wisconsin
		Mankato	
		Cary	
Madeleine		Tazewell	
Madeleine, Solutrian, Aurignacian	(?) Homo saloensis (?) (Neanderthalensis)	Iowan	
Aurignacian, Moustier		Peoria interglacial	
		Iowan (?) - Ronkonkoma glaciation	
Moustier [Taubach, Carmel (Tabun) Krapin]		Sangamon interglacial	
Well developed Levalois Late Ashell		Illinois glaciation	
Middle Ashell			
Early Levalois Klekton or Takan Early and Middle Ashell			
Early Ashell Klekton II	Swanscombe man	Yarmouth interglacial	
	Homo madjokensis of the Pithecanthropus group	Kansas glaciation	
(Rabat) Homo heidelbergensis			
Abbeville Klekton I		Afton interglacial	
"Eoliths"		Nebraska glaciation	

Table 2 (Cont'd)

A Suggested Subdivision and Correlation
of the Quaternary (Anthropogene) System

<table>
<tr><th colspan="5">A F R I C A</th></tr>
<tr><th colspan="5">After Aramburg, Lecky, Aliman, Zeiner, etc.</th></tr>
<tr><td rowspan="2">Post-gamblian</td><td>Nakuri</td><td colspan="2">Neolithic</td><td rowspan="2">Homo sapiens</td></tr>
<tr><td>Makali</td><td colspan="2">Mesolithic</td></tr>
<tr><td rowspan="4">Gamblian</td><td rowspan="3">4th pluvial</td><td rowspan="3">Feresmith Atherian</td><td>Capsian, Stilbey -- Sebilian, Oldway V</td><td rowspan="3">Neanderthal man from Broken Hill and other
Homo sapiens from Boscona and other</td></tr>
<tr><td>Protostilbey, Lupembian, Levalois</td></tr>
<tr><td>Moustier, Levalois</td></tr>
<tr><td>Arid</td><td rowspan="4">Shell-Ashell</td><td>Mikok, Sango, Kalinian, Late Ashell</td><td>Neanderthal man</td></tr>
<tr><td rowspan="2">Kanyerian</td><td>3rd pluvial</td><td>African Ashell
Oldway IV</td><td>Rabat man</td></tr>
<tr><td>Arid</td><td>Oldway III
African Shell</td><td>Paranthropus,
Telanthropus</td></tr>
<tr><td rowspan="2">Kamazian</td><td>2nd pluvial</td><td>Oldway I - II</td><td>Atlanthropus</td></tr>
<tr><td>Arid</td><td></td><td>Early Oldway</td><td>Plesianthropus,
Australopithecus africanus</td></tr>
<tr><td>Kagerian</td><td>1st pluvial</td><td>Gravel culture</td><td>Well developed Kafoo
Ancient Kafoo</td><td>Australopithecus prometheus
and others</td></tr>
</table>

Table 2 (Cont'd)

A Suggested Subdivision and Correlation
of the Quaternary (Anthropogene) System

<table>
<tr><td colspan="5">CHINA</td></tr>
<tr><td colspan="3">After Cho Min-chen, Li Si-huan, Barbur</td><td colspan="2">Pei Ven-chun, 1957</td></tr>
<tr><td colspan="2">New recent epoch</td><td>Holocene</td><td colspan="2">Mesolithic
Kikhsiangtun, near Harbin
+ (Chalai-Nor, near Manchuria
(Harbin Paleolithic)</td></tr>
<tr><td rowspan="6">Pleistocene</td><td rowspan="2">Late</td><td rowspan="2">Vek Huantu
(loess)fauna
Elephas primigenius,
Pseudaxis, Hyarna ultima,
Struthio,
Paradoxurus,
Ursus spelaeus</td><td rowspan="2">Loess [age]</td><td>Late Peshch
Cho-Ko-Tien
Tseiyang man
Ordoss man
(Syaro-Osso-Gol and
Cho-Tong-Ko)</td></tr>
<tr><td>Tringtsun man</td></tr>
<tr><td rowspan="2">Middle
early/late</td><td rowspan="2">Cho-kotien age fauna:
Palaeoloxodon nomadicus,
Rhinoceros cf. tichorhinus,
Ursus spelaeus, Cinomegaceros,
Ursus deiningeri, Spirocerus,
Rhinoceros mercki,
Trogontherium cuvieri,
Machairodus, etc.</td><td rowspan="3">Chzou-Kou-Tyan'
(or upper San-Myn')</td><td>Cho-Ko-Tien
sites
No. 15, No. 3, No. 4</td></tr>
<tr><td>Cho-Ko-Tien
bed with Sinanthropus</td></tr>
<tr><td rowspan="2">Early</td><td rowspan="2">Nikhevan age
fauna:
Machairodus,
Trogontherium cuvieri,
Nyctereules sinensis,
Equus sanmeniensis,
Elephas, Postchisotherium,
Hipparion sp.,
in South China: Stegodon
Tapirus, Chalicotherium,
etc.</td><td>Cho-Ko-Tien
site No. 13</td></tr>
<tr><td colspan="2">Nikhevan
or
Early San-Min</td></tr>
</table>

Table 2 (Cont'd)

A Suggested Subdivision and Correlation of the Quaternary (Anthropogene) System

<table>
<tr><td colspan="3">INDIA, INDONESIA</td></tr>
<tr><td colspan="3">After Siebing, Krishnan, Vadia</td></tr>
<tr><td>holocene</td><td colspan="2">Postglacial deposits</td></tr>
<tr><td rowspan="2">Nagandong</td><td rowspan="3">Potuar</td><td>Glaciation 4
(Würm, after Siebing)</td></tr>
<tr><td>Interglacial 3</td></tr>
<tr><td rowspan="2">Trinil</td><td>Glaciation 3
(Riss, after Siebing)</td></tr>
<tr><td rowspan="2">early and late Carew</td><td>Interglacial 2</td></tr>
<tr><td rowspan="3">Djetis</td><td>Upper boulder conglomerate
Glaciation 2 (Mindel, after Siebing)</td></tr>
<tr><td>Pindjor</td><td>Lower boulder conglomerate
1st interglacial fauna: Pentaphadon, Stegodon,
Archidiscodon, Equus, Capra, Leptobos,
Bubalus Bos, Bison, Giraffa, Cervus, etc.</td></tr>
<tr><td>Tatrot</td><td>? Bein boulder conglomerate
Glaciation 1 (Günz, after Siebing)
fauna: Pentalaphodon, Stegoden,
Equus sivalensis, Hipparian, Sus, etc.</td></tr>
</table>

THE GEOLOGIC AGE OF THE PALEOLITHIC IN THE U. S. S. R.[1]

by

V. I. Gromov and Ye. V. Shantser

More than 20 years ago soviet investigators recognized the necessity for serious reconsideration of the geologic age of the Paleolithic; this suggestion was accepted at that time. Those concepts based on the study of Paleolithic monuments in western Europe were not consistent with new facts which became known in the U.S.S.R. In 1936, G.F. Mirchink [15], V.I. Gromov [3], and P.P. Yefimenko [8] in papers presented at the Third Congress of INQUA in Vienna (1936), clarified some fundamental conceptions. Their main point was the recognition of substantially greater age and substantially longer duration of all stages of the development of material culture in Paleolithic time than was believed previously. Later, in 1938, the paper of V.I. Gromov [4] was published, in which he used much new material. He started a detailed argument on a new point of view on the geologic age of the Paleolithic, which has now received wide acceptance in the Soviet Union. In brief form, geologic and archeologic proof of the correctness of the new point of view was expressed in 1950 in the articles of V.I. Gromov [5], P.P. Yefimenko [9], P.M. Boriskovskiy [1]. Besides these, the basic conclusions on the geology of the Paleolithic in the U.S.S.R. were published by V.I. Gromov, G.A. Bonch-Osmolovskiy, G.F. Debets, and Ya. Ya. Roginskiy in the Works of the XVI and XIX Sessions of the International Geological Congress [7, 26, 29].

It is necessary to stress that if the preliminary revision of old conceptions was based on a relatively small number of facts, the problem is now absolutely different. Now, within the Soviet Union, more than 300 paleological remnants are known; and they have been more or less well studied by geologists and archaeologists. They are scattered over a huge area from the western borders of the country almost to the shores of the Pacific Ocean and include all stages of development of paleolithic culture: from the late Chellian to the end of the Late Paleolithic.

As was shown in the discussions at the All-Union Conference on the Study of the Quaternary Period that took place in May 1957, the analysis of such huge and varied material, in general, supports the correctness of the basic conceptions which were proposed by G.F. Mirchink and V.I. Gromov. The new facts, published in recent years, required only small changes and a higher degree of accuracy in the development of new schemes and on separate problems.

In the countries of western and central Europe during the last 20 years, a considerable evolution of concepts on the geologic age of the Paleolithic has also occurred. In particular, the opinion is widely accepted that the Early Paleolithic embraces a very long period of time and its beginning is deep in the Pleistocene. In this respect, the Soviet point of view and the point of view of western European investigators are evidently coming closer. However, in western Europe, until now, the popular conceptions of the age of Moustier and the Upper Paleolithic are very close to, if not the same as, the old schemes of Mortillet and Renck [31, 33] and even M. Baule and H. Obermaier [24, 32], according to whom these stages of paleologic culture were fully developed in Riss-Wurn and Wurn Age. The majority of Soviet geologists and archaeologists are definitely against this timing and consider that the Upper Paleolithic, and especially Moustier monuments, are the relics of an earlier age of the Pleistocene. Because of some sharp discrepancies there is a necessity to find the reasons for them and achieve a united opinion. The solution of this problem is very important not only from the special archaeologic or paleoanthropologic point of view, but it is of great importance for the correct understanding of evolution in geographic environments and in the entire

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[1] Paper presented at the Fifth Congress of the International Association for the Study of the Quaternary Period. Madrid, September 1957.

geologic history of the Quaternary period.

The purpose of this paper is to begin a wide international discussion on the problem of the geologic age of the Paleolithic, although it is quite evident that the whole solution of this problem cannot be achieved simply by its formulation. It is necessary that a special international conference with the participation of archaeologists and Quaternary geologists of several countries be carried out; a special investigation with joint excursions into the most characteristic regions and to the sites of the most important Paleolithic discoveries of Western Europe and the Soviet Union are also necessary. The above-mentioned All-Union Conference in 1957 recognized the necessity for the immediate beginning of such work, and several Soviet scientific organizations are already trying to call, at the earliest in one or two years, the first, limited, international convention. It seems that such a competent organization as INQUA could possibly take the initiative and organize this work on a wider scale.

We want to stress that many points of the problem can be clarified on the basis of Paleolithic discoveries in the U. S. S. R. This convention based conclusions on the sober evaluation of the geologic condition of deposition of remnants. The overwhelming majority of Paleolithic remnants of the Soviet Union do not occur in caves, but are the settlements of the so-called "open type," cultural remnants which are buried directly in Quaternary deposits, occupying there, as a rule, a very distinct and clear stratigraphic position. And they are not thin gravel veneers over erosional river terraces or gravelly slides of mountain slopes, but in many cases they are measured by tens of meters of accumulated alluvial and deluvial deposits in the valleys of rivers across the plain, or by the thick loess deposits divided by numerous buried soils and sometimes distinctly correlative with glacial formations and marine sediments. The cultural layers of such settlements are, for a geologist, an object analogous to any paleontologically-characterized horizon of a type section. Such stratigraphically well-indexed monuments were the reason for reevaluation of old concepts. Let us consider the facts alone.

Probably the most typical conditions of deposition are expressed by the numerous Middle Paleolithic Mustier deposits in the U. S. S. R. At the termination of these deposits we will therefore start.

From Moustier remnants and monuments it is possible to isolate two groups which are considerably different both in the geologic situation in which they occur and in the remnants of fauna and the typology of quartz utensils. The first group of Moustier monuments can be related archaeologically to the early and partly-developed Moustier. First of all, it is necessary to mention the solitary findings of typically Moustier chips, scrapings and arrowheads at the Desna River where they have been taken from deposits underlying the drift of maximum (Dnieper) glaciation of the Eastern European Plain (Yazvi, Arapovichi, Pushkari). Up to the present, no one has doubted the correlation of the Dneprovskiy glaciation with the maximum stage of Alpian Riss and Zaal glaciation of North Germany; thus, there is no ground to doubt the pre- or early Riss age of these findings.[1]

This conclusion is well supported by the condition of deposition at the Moustier settlement near Kodak village close to Dnepropetrovsk, just south of the border of the Dnieper glaciation. The settlement near Kodak village is in alluvial lacustrine deposits of a high terrace in the lateral valley, entering the Dnieper from the right; the deposits are buried under loess 20 to 25 meters thick with layers of buried soils. Morphologically, the Kodak terrace ties in well with the so-called Fifth Terrace of Dnieper, according to the terminology of Ukrainian geologists. This latter terrace is slightly higher than the Dnepropetrovsk terrace and was overlapped by drift of the Dniepean glaciation; the age of its alluvium and consequently of the Moustier settlement in Kodak, is pre- or early Riss.

In analogous stratigraphic position, Moustier weapons and chips were found in the basin of the Don on the northern shores of the Azov Sea near Bessergenovka and Lakedemonovka villages. At the last two points, the chips and scrapings of Moustier character were found in the thick loess overlying the second terrace of the seashore consisting of the sands of the so-called ancient Yevksinsk unit of the marine Black Sea deposits. Didacna ponto-caspia Pavl. and Paludina diluviana Kunth, which is undoubtedly of Early Pleistocene Age, were found here. The thickness of loess covering the terrace is 15 to 20 meters; it contains two well-developed and consistent horizons of buried Black Sea soils. In this condition and from the other details of structure, this loess thickness is completely identical to the loess

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[1]Recently A.I. Moskvitin 12 made a supposition on the possibility of correspondence between Dnieper glaciation and the Mindel of the Alpian scheme, but not the Riss. In this case the Moustier findings on the Desna will be even older. However, this proposition is rejected by the overwhelming majority of Soviet geologists.

cover of the Fifth Lower Pleistocene terrace of the Dnieper, south of the border of Dnieper glaciation, where two horizons of buried soils are correlated with Riss-Wurn and Mindel-Riss of the Alpian scheme, dividing and covering formations of loess correlated with the Riss and Wurn. Moustier weapons on the Azov shore were found in the lower loess covering the second-from-the-top buried soil, i.e., by analogy with the valley of the Dnieper, in early Riss deposits. During the Second Congress of the INQUA, these sections were shown to the delegates, and their interpretation has been accepted [19].

Pre-Riss or Early Riss Age of Moustier monuments is quite convincingly demonstrated also for the Black Sea shore of Caucasus on the Abkhaziya border. Earlier, all the chips of Moustier type were found in lateral moraine of the maximum Caucasian glaciation in the lower part of the Kodor River near Tsebelda village. Because the maximum glaciation of the Caucasus is unanimously correlated with the Riss glaciation of the Alps, the Pre-Riss or Early Riss Age of this finding is not doubtful. The majority of findings of Abkhazian Moustier are distributed, however, in different conditions. Here at 23 points along the Black Sea shore area bountiful accumulations of typically Moustier utensils, generally deposited in upper shale and clayey sand on the surface of the third shore terrace, 32 to 40 meters above sea level. On the Abkhaziya border this terrace is composed of pebbles which are the estuary accumulation of rivers flowing from Caucasian mountains. The clay sands which cover these pebbles have the same origin.

It is possible to reason that Moustier Man populated the area of the terrace at a time when the accumulation of these deposits was not yet completed, i.e., that Moustier settlements are contemporaneous with the river sediments of the terrace. This is supported by the fact that neither on the higher fourth shore terrace (about 60 meters high) nor on the lower terrace (15 to 20 meters) are there known Moustier monuments <u>in situ</u>. Only in secondary deposits were Moustier remnants found redeposited on alluvial cones in the ravines and in deluvial material on the slope of the third terrace to the back part of the second terrace. On the fourth terrace in more than ten places an accumulation of the remnants of a considerably older, typically Klektonic or Upper Neochellian type were found in primary deposits, and on the second terrace, remnants of Upper Paleolithic settlements were found. This can be explained by the fact that the settlements of Paleolithic Man were usually close to the level of the river which deposited pebbles and silt and was the source of water. With the cutting of the river valley and lowering of the water level, the line of Paleolithic settlements on Abkhaz shore descended to a lower terrace.

The third terrace, with which the Moustier deposits are correlated, proved to be older than the river terraces along the valley of Mzymta, Kodora, and other rivers, and with the lateral moraines of maximum glaciation, i.e., Riss glaciation. In the northwest at the region of Sochi-Tuapse this terrace changes into a morainic terrace with the fauna of the so-called Uzunlar unit of the Black Sea deposits, usually correlated with Mindel-Riss or the beginning of Riss of Alpian time.

A Pre-Riss or Early Riss Age of Abkhazian Moustier has, therefore, sufficiently strong proof. The Klekton and Upper Achellian, they are related to older deposits. The fourth terrace with which they are correlated, changes in the region of Sochi into an erosional terrace with the fauna of the ancient Yevksinsk unit correlated with the Mindel and beginning of the Mindel-Riss of the Alpian scheme.

In recent years, it was again supported by the excavations in the newly-found Moustier settlements near Stalingrad on the Volga [2, 6, 12]. Here the layer with cultural remnants is in the upper alluvial deposits supposedly correlated with the so-called Khazar formation which overlies the Atel unit by 15 meters of clay-silt having two buried soils in the lower part; much higher, there is sand and clay of the Khvalyn formation of the ancient Caspian deposits, 4 to 5 meters thick, with <u>Didacna</u> and <u>Dreissensia</u>. From the analysis of ancient Caspian deposits and their correlation with the terrace on the Volga River, and the correlation of this terrace with the last glacial formation of the middle part of the Eastern European clay, it is clear [15] that the Khazar layers cannot be younger than the maximum, i.e., Riss glaciation. The deposits of the maximum Khvalyn transgression of the Caspian Sea correspond to those of Wurn Age; Atel layers occupy the intermediate position. In particular, it is quite possible that the buried soils at the bottom of the Atel layers correspond to Riss-Wurn. Hence, the Stalingrad Moustier settlement is not very likely younger than Riss, although its age could be more precisely determined.

It is necessary to stress that nowhere in the glaciated region of the Eastern European Plain were Moustier remnants found stratigraphically above or in the Dnieper drift, which is considered younger than the underlying drift. This is also an important indication of the probable geologic age of the

Moustier since the number of Moustier weapons found in the U. S. S. R. is substantial.

The above data, however, are useful only in determining the lower age boundary of the Moustier, since they concern exclusively the early Moustier monuments or the developed Moustier. However, in the U. S. S. R. there is known also another group of locations with Late and Final Moustier. The principal archaeologic features of this group were recently described by V. P. Lyubin and A. A. Formozov [14]. Characteristic for these monuments is the presence of basically different conditions of geologic deposition. The most representative monuments are near Il'sk, Northern Caucasus; at Starosel'ye near Bakhchisaray, Crimea; and near Molodovo village (Baylova Ripa) on the Dniester.

The Il'sk settlement is archaeologically the most explored. The nature of the silica inventory indicates characteristics resembling the Upper Paleolithic along with obvious Moustier features. The settlement is related to the second terrace in the river valley of one of the Kuban' River tributaries. On the basis of the geology, the remains of the settlement cannot be older than the end of the Riss or even the Riss-Wurn [Wurm?]. The position and typologic peculiarities of the Late Moustier settlement in Starosel'ye in the low terrace are absolutely analogous. They are correlated, according to M. V. Muratov [15] with the so-called Karanga marine terrace of the Black Sea shore. Karanga marine deposits, containing a rich molluscan fauna of the Mediterranean type (Cardium tuberculatum, Tapes calverti and other forms), are correlated with the Riss-Wurn of the Alpian scheme by an overwhelming majority of geologists. Their accumulation, however, was preceded by the deep entrenchment of streams in parts of the river valleys, because the streams discharge into the Black Sea, whose bed is 40 meters below the contemporary level of the sea, and they fill it with sediments. The deposition of pebble beds was contemporaneous with Riss glaciation. On the basis of purely geologic and geomorphic data it is difficult to say which of the two periods of Cargan terrace development correspond to the settlements in Starosel'ye.

The position of the settlement of Molodovo village on the Dniester River is similar. It was discovered more than 27 years ago by the Rumanian scientist, I. Botez [27, 28] and described in the work of Morosan in 1938 [30]. However, detailed excavations were first carried out here in 1946-1957 by A. P. Chernysh with the participation of I. K. Ivanova, who studied the geologic conditions. A full treatment of the new archaeologic and paleontologic material has not yet been carried out, and the general picture resulting from this finding has not yet been made sufficiently clear. The location, discovered by Botez (Molodovo-I) of a Later Moustier culture layer with abundant quartz tools, animal bones, and a fossil campfire, is situated at the base of the second terrace in the Dniester River. The occurrence is covered by the alluvial cone of a ravine which was cut in the side of the Dniester Valley during development of the valley after formation of the second alluvial terrace. This terrace is definitely of Early Wurn Age. The epoch of incision of valleys in the basins of the Dniester, Southern Bug, Dnieper, and all rivers of the southern part of the Eastern European Plain is well correlated with the end of Riss time (time of regression of the second, so-called Moscow stage of glaciation, sometimes believed to be an independent glaciation, corresponding approximately to the Wart stage in Poland and Germany).

Therefore, the age of Later Moustier settlements in Molodovo is found to correspond to the end of Riss or beginning of Riss-Wurn time, similar to Il'sk and Starosel'ye.

A later Riss or Early Riss-Wurn Age for the Late Moustier is consistent with the faunal characteristics of these settlements. Everywhere it contains numerous remnants of the true mammoth Elephas primigenius Blum; which appeared at first in Eastern Europe during the maximum Dnieper glaciation, as testified to by the discovery of a part of a skeleton under the drift of this glaciation on the Dnieper. The fauna of Il'sk village is known better than any other, and it includes the representatives of a plains complex, which always later accompanied the mammoth in the fauna of the Upper Paleolithic (Bison priscus, Saiga tatarica, and other forms). The elements of an entirely different, clearly older faunal complex, accompany the monuments of earlier and fully developed Moustier culture. Judging from settlements in Kodak near Dnepropetrovsk an archaic type of elephant -- Elephas trogontherii Pohl -- is more characteristic of the caves of Kiik-Koba and Chokurcha in the Crimea. This elephant is undoubtedly the ancestial form of the real mammoth (together with such forms as Bison priscus var longicornis W. Grom, Magaceros germaniae Pohl, Equus chosaricus W. Grom, and other forms. This fauna is typical of the so-called Khazar faunal complex of V. I. Gromov [3, 4], the greatest deposits of which are known in alluvial facies of the Khazar formation of Cis-Caspian plain and contemporaneous deposits on the Volga and Lower Kama. This Khazar faunal complex occurs in the layers corresponding to about the end of the Mindel-Riss and the very beginning of Riss in the

Alpian scheme. The fauna of Upper Moustier deposits differs from it by appearance or absence in typical sections of high borealic and polar forms (Rangifer tarandus L. in Kodak settlement in Kiik-Koba caves in Crimea, Vulpes lagopus L. in Kiik-Koba and Adzhi-Koba caves in Crimea, etc.). This suggests the correlation of early Moustier with the beginning of Riss time.

Therefore, the Middle Paleolithic or Moustier in the U.S.S.R. embraces as a whole a very great period of time: from the end of Mindel-Riss and the beginning of Riss to the Later Riss or the beginning of Riss-Wurm, inclusive. Roughly, Moustier coincides with the Riss Age. But it is necessary to stress that more detailed dating of separate settlement and stages of development of the Moustier is still very difficult. In particular, in the eastern European Plain, two large phases of increase in extent of glaciation during Riss Age have been recognized: Dnieper and Moscow, divided in time by the so-called Odintsov Epoch of climatic warming and considered by some as interstadia, by others as interglacial. It is quite possible that certain definite differences in climatic environment influencing the fauna in different Moustier settlements in Crimea, can be explained just by this climatic fluctuation during the Riss Age. However, we wish to be more conservative and not make any concrete comparison.

Before discussing the justification for the geologic age of the Upper Paleolithic we shall discuss the Aurignac in the U.S.S.R. In the 1930's both in Soviet and foreign archaeological literature, many Upper Paleolithic settlements of the eastern European Plain were included in the Aurignac. Some of them, such as Mezin, Suponevo, Pushkari-I are, according to the condition of deposition, Riss-Wurm or Early Wurm. Others such as Zhuravka, Yeliseyevichi were quite correctly included by geologists (D.F. Mirchink and V. Reznichenko) [16, 20, 21], in the Wurm or even in the end of the Wurm. This was also true for several settlements discovered on the Dnieper River by Rumanian investigators [30]. After detailed study of all these findings the fallacy of the initial archaeologic dating was discussed. The settlements, similar to Mezin, Suponevo, Pushkari-I proved to be Solutreian; and Zhuravka, Yeliseyevichi, and the majority of Dniester findings are included in the Late Madlene [10]. At present there is no doubt on this subject among Soviet archaeologists; in the meantime all reasons for correlating the Aurignac with Riss-Wurm and Wurm were completely discounted.

Besides, it is now possible to insist that typical Aurignac is not present in the U.S.S.R. at all. Certain Crimean settlements (Syuren'-I) are closer than anything else typologically to the Western Aurignac but they also have their own characteristic features. In the eastern European Plain, even the most ancient Upper Paleolithic monuments (Tel'man settlement on the Don) show in their typology of quartz utensils distinctly Solutrean features [10]. Furthermore, the settlements of earlier stages of the Late Paleolithic are absent in the area occupied by the Dnieper and Don flats of maximum glaciation, similar to the zone along the border of the extra-glacial region.

Taking into consideration what was said above about the age of the Late Moustier, it is easy to suppose that the change from Moustier to Late Paleolithic could take place in eastern Europe in the first part of Riss time; and Aurignac Man could not have populated the area of glaciation. It is significant that in the Crimea settlements most closely resembling Western Aurignac, traces of the sharpest cooling of climate are observed. Numerous findings of such cold-loving and clearly polar types as Rangifer tarandus, Vulpes lagopus, Lepus tumidus (Lagopus lagopus), and (Phyrrhocorax graculus), were made in these Crimean localities. It is quite reasonable to associate the sharp cooling, accompanied by the wide distribution of cold-loving forms even in Crimea with the stages of maximum, i.e., Riss, glaciation, but not with Wurm as was usually done. An important argument for such a supposition is made by the very numerous Solutrean and Madlene settlements in the eastern European Plain. They are especially numerous in the zone situated between the borders of maximum (Dnieper) and Wurm (Valday) glaciation, including in these limits the Dnieper and Don glacial flats.

Especially significant are the conditions of deposition of the settlements in the basin of the Dnieper and its large left tributary, the Desna [11, 15]. The structure of Quaternary deposits in the scheme here is as follows: On the interfluvial divide and ancient river terraces covered by Dnieper drift, loess 4 to 8 meters thick is divided by a slightly-developed, thin, buried soil into two parts. The loess covers the slope of the valley and downslope gains in thickness, grading into stratified loess clay of deluvial and alluvial origin. Clay of this type entirely overlies the so-called third or "uniloess" terrace (according to the terminology of Ukrainian geologists), where it changes into estuarian alluvial sand. A younger sand terrace undoubtedly of Wurm Age is adjacent to the "uniloess" terrace. This was established by correlation with the glacial formation in the upper reaches of the rivers and by the presence of microlithic monuments in the

top horizon of the terrace. The "uniloess" terrace itself also consists chiefly of Early Wurn alluvium equivalent to the glacial formation in the sources of the Dnieper and its upper tributaries. In regard to the loess of the interfluvial divide, which partly changes in facies, the "uniloess" terraces partly overlie the latter; hence, its age is evidently also Wurn. The weakly-developed buried soil dividing the loess is correlative with the interstadial WurnI-Wurn II or "Mologo-Sheksna Interglacials" of A.I. Moskvitin (the second new interglacial of S.A. Yakovlev [17, 23]). Loess is underlain by well-developed buried soil; in southern regions, it is always of the steppe-type; in northern regions it is sometimes of the forest-type. This soil can be correlated with Riss-Wurn of the Alpian scheme. In the sources of the Dnieper (Kletsovo village and other points) this soil in places is replaced by buried peat with a typically Riss-Wurn broadleaved flora and the seeds of Brasenia purpurea Sehroet. On the divides, Riss-Wurn soil is developed on thin fluvioglacial sand and clay, covering Dnieprean drift; on the slopes of the valleys, the Riss-Wurn changes directly into drift. Farther below, the soil on slopes wedges out and the loess and alluvium of the deeply eroded "uniloess" terrace lies on pre-Quaternary rocks. This erosion occurred at the end of the Riss or Riss-Wurn. Several Late Paleolithic settlements of the Solutrean type (Pushkari-I, Mezin, Sukonevo) are correlated with the surface of Riss-Wurn buried soil, and lower parts of the overlaying loess and loessial alluvial-deluvial formations. Therefore, their age can be Riss-Wurn or at the earliest, Wurn. A Riss-Wurn Age of Solutrean settlements is also confirmed by Paleolimnologic investigations carried out on the Don.

Pollen analysis, carried out by M.P. Grichuk, from Solutrean settlements Kostenki-I has revealed up to 41 percent tree pollen of a total sample of 177 to 335 spores and seeds. In certain horizons, the prevailing coniferous (pine and spruce) pollen made up 47 to 78 percent. But even in these cases, a certain admixture of pollen from broadleaved types (Alnus, Tilia, Quercus, Ulmus) of 22 to 41 percent was counted. In other samples its content was even higher, up to 49 percent, and the coniferous pollen dropped to 19 percent. Contemporaneous hazelnut (Corylus) reached 76 percent. It is easy to conclude that the flora around the settlement was sufficiently warmth-loving and approached, in places, the typical flora of Riss-Wurn interglacial peat of eastern Europe [13]. The generally uniform faunal complex of mammals called by V.I. Gromov "Upper Paleolithic" [3, 4] is characteristic of the entire Upper Paleolithic of the U.S.S.R. The most typical representative is a mammal (Elephas primigenius Blum).

However, considerable differences exist between the fauna of the Late Paleolithic (Aurignac), "Solutrean," and "Mandlene." So, for settlements of the Aurignac type, the prevalence of northern, distinctly cold-loving forms, such as Rangifer tarandus, and Vulpes lagopus are characteristic. Distinctly expressed "glacial" types appear in the fauna of the Madlene settlements; the remnants of the typically tundra animals and such forms as Dycrostonix torquatus are very abundant. Contrary to this, the fauna of Solutrean settlements is the characteristic "mixed" type. Together with remnants of northern forms (Rangifer tarandus and sometimes Vulpes lagopus), there are abundant, typically steppe forms such as Saiga tatarica, Alactaga jaculus, Cricetus cricetus, not to mention numerous Equus and Bison. Besides, from the same settlements are the less abundant remnants of distinctly forest animals, for example, Cervus elaphus, Ursus arctos, and Gulo gulo. The Solutrean fauna clearly coincides with the time of climatic warming which divides two cold epochs.

Madlene settlements on the Dnieper and Desna (Chulatovo-II, Zhuravka, Gontsy, and others) are associated more often with the overlaying loess-like rocks of the "uniloess" terrace and the deluvial formations, which correspond stratigraphically to the top of the loess series on divides or are even younger. They, therefore, are undoubtedly Wurn; this is confirmed by the character of fauna and flora and is evidence of a very cold climate. However, some of the deposits in the upper level of alluvium of the Early Wurn terrace testify that the Madlene in U.S.S.R. falls not only at the end or in the second half of the Wurn, but embraces a considerably larger part of the Wurn Age.

In summary, it is evident from the facts above that our conclusions on the geologic age of the Paleolithic differ sharply from the scheme of Mortillet and Renck and even to a greater degree from the scheme of M. Obermaier, which is still accepted in western Europe. Our schemes are closer in basic conception to the scheme expressed by J. Bayer [25] and V. Soergel [34], but they do not fully coincide. In the U.S.S.R., the geologic age of Early and Late Moustier is very clearly established; the age of the Solutrean and Madlene is also well established. Earlier Moustier proved to be Pre-Riss or Early Riss. Late Moustier is correspondingly correlative with maximum Riss (Dnieper) glaciation. And hence it is clear that all earlier stages of the Paleolithic can be dated as not later than Mendel-Riss (Klekton, Upper Achellian) and purely lower Paleolithic (typical Achellian and Chellian) as

Mendel or even as the very beginning of the Pleistocene, up to Villafranc time. Let us note that this is not contradicted by geologic or paleontologic data of known deposits containing Sinanthropus in China and Pithecanthropus on Java. Solutrean in the U.S.S.R. is also distinctly dated as Riss-Wurn or beginning of Wurn, and Madlene as partly Wurn. Less distinct is the stratigraphic position of the latest Moustier and early stages of the Upper Paleolithic, corresponding to the western Aurignac. They, evidently, fall into the second part of the Riss and the beginning of Riss-Wurn. It is necessary to note that the possibility of contemporaneity between Late Moustier and early forms of Late Paleolithic culture in different regions of the U.S.S.R. is not precluded. However, their originality in typological relation to each other in itself does not require contemporaneity. Besides, the historic and archaeologic importance of finding Moustier in the U.S.S.R. is not quite clear, especially considering the fact that in one of the settlements of this type in Starosel'ye in Crimea, the remnants of a man related to Homo sapiens and not to Neanderthal, the representative of typically Moustier culture [14, 22], has been found. From these short notes the complexity of the problem is evident. The contradictions arising at present in the determination of the geologic age of the Paleolithic [35], of course, could be chiefly the result of erroneous interpretation of certain geologic and archaeologic facts. Those reasons for contradiction are easy and simply solved through the collective revision of data on specific Paleolithic monuments. It is possible, however, that reasons of another kind may cause errors which can be corrected only with greater difficulty. We have in mind differences in the process of change in form of Paleolithic cultures, and maybe in anthropologic types of man himself in different parts of the Eurasian continent. Some of these differences are already expressed, but it is still difficult to say how deep and sharp they really are. However, the discussion of this part of the problem is out of the frame of the present papers and will be the object of further discussion.

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UPPER DEVONIAN AND LOWER CARBONIFEROUS DEPOSITS AND ASSOCIATED IRON-MANGANESE ORES OF THE DZHAIL'MA SYNCLINE (ATASUY REGION OF CENTRAL KAZAKHSTAN)

by

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ABSTRACT

Three genetic types of Upper Devonian and Lower Carboniferous deposit are distinguished by the author in the Dzhail'ma syncline. The characteristics of each type are described, and special attention is devoted to deposits associated with the ferromanganese ores of Karadzhal. A few considerations dealing with the genesis of these ores are stated.

* * * * *

The study of the Upper Devonian and Lower Carboniferous deposits of the Dzhail'ma syncline is of practical interest in view of the connection existing between them and the ferromanganese mineralization. A comparative analysis of sedimentary sections of these systems in various parts of the region permits an evaluation of the peculiarities of sedimentary accumulations at the time of mineralization. Such an analysis would also reveal the type of sedimentation with which the ore deposits are associated. Research of this nature helps to clarify the problem of ore genesis and to evolve certain criteria for prospecting.

The composition and sedimentation conditions of the Upper Devonian and Lower Carboniferous deposit in the region mentioned are fairly complex and cannot be fully discussed in one brief article. In this study attention is centered mainly on certain controversial aspects of this extensive subject.

In general outline, the Devonian and Lower Carboniferous section in the Dzhail'ma syncline may be summed up as shown in Table 1.

1. At the base of the section there is a series of mainly volcanic rocks, characterized by two beds; from the bottom up they are:

a) D_{1-2} Albitophyres and tuff.

b) D_2 Red quartzose porphyry and tuff.

The age of these formations is only tentative because no discoveries of organic remains have been made in these rocks.

The whole series is believed to be Devonian by analogy with the sections of other regions of Kazakhstan, farther North (the Nurinsk synclinorium) in which volcanic formations, similar to those described, are underlain by sedimentary deposits with a Silurian fauna [5]. The upper age limit of this series was determined by the Upper Devonian flora collected in this variegated formation. The thickness of the series is 800 to 1200 m.

2. D^1_3. A variegated, fragmental formation, mainly terrigenous, and volcanic in origin. The contact between this formation and the formations beneath it is not uniform. In places, this formation rests unconformably on various layers of the Devonian volcanic series, at other places it is connected with the latter beds by gradual transition.

Table 1

Comparative Stratigraphic Sections of the Dzhail'ma and Zhilandinsk Synclines

Systems	Series	Stages	Sub-stages	Form-ations	Section I Dzhail'ma syncline (western portion)	Section II Dzhail'ma syncline (Karadzhal'sk deposits region)	Section III Zhilandinsk and eastern portion of Dzhail'ma syncline
Carboniferous	Lower	Visean			Interstratification of coarse and fine siltstones with argillites and sandstones. Occasional seams of concentrated coals. At the bases limestone layers occur. Fauna: Posidonia becheri Broun. Vegetation remnants. Lepidodendron kirghisicum Zal.		
		Tournaisian	Upper		Argillaceous limestones and marls. Fauna: Muensteroceras kasakstanicum Libr., Pericyclus cf. asiaticus Libr.	Fine-grained, silico-argillaceous-carbonate formations, quartzites, tuffites; in upper horizons, layers of siltstones and argillites.	
			Lower		Thick, tabular reef limestones. Fauna: Productus (Linoproductus) laevicostus Nhite., Spirifer cf. kosak Nal, Sp. (Spirifer) kasadek Nal. Sp. (Spirifer) sibiricus Leb., Productus kassini Nal.	Fine-grained, silico-argillaceous-carbonate formations, tuffites, subordinate layers of ash tufas and limestones. Fauna: Productus ex gr. femglenensis Well., Pr. (Spinulicosta) concentricus Hall., Spirifer kasacek Nal., Sp. sibiricus Leb., Ambocoelia cf. unionensis Well., Chonetes setigera Hall.	Reef limestones with subordinate layers of fine-grained, silico-argillaceous carbonate rocks. Fauna: Productus (Chonetipustula) cf. kassini Nal., Pr. (Spinulicosta) cf. concentricus Hall., Ambocoelia unionensis Well., Chonetes cf., ornata Shum.

Table 1 (cont'd)

Comparative Stratigraphic Sections of the Dzhail'ma and Zhilandinsk Synclines

Systems	Series	Stages	Sub-stages	Form-ations	Section I Dzhail'ma syncline (western portion)	Section II Dzhail'ma syncline (Karadzhal'sk deposits region)	Section III Zhilandinsk and eastern portion of the Dzhail'ma syncline
Devonian	Upper	Famennian			Reef limestones. Fauna: Spirifer ex gr. sulcifer Hall., and Clark., Cyttospirifer semisbugensis Nal , Disciha sp.	Fine-grained, silico-argillaceous-carbonate rocks, clayey and siliceous, fine-grained limestones; in upper horizons, layers of effusives of the spilitic type, their tuffs, jasper, lenses of iron-manganese ores. Fauna: Varioclymenia pom peckji Wed., Buchiola n. sp., Posidonia venusta münst.	Consertal sandstones, siltstones, silico-argillaceous-carbonate rocks, sandy limestones and dolomites. Fauna: Productus (Plicatifera) cf. semisbugensis Nal., Cyttospirifer cf. kurbon Nal., Chonetes cf. hardrensis Phill.
		Frasnian			Repeated interstratification of red-borate sandstones, siltstones, normal and acidic lavas and their tuffs. Lenses and layers of conglomerates. Fossil flora: Heleniella cf. Theodore Zal. Leptophloeum rhombicum Daws.	Red-borate sandstones with lenses and interbedded coarse- and fine-grained conglomerates and siltstones. Abruptly subordinate layers of acidic lavas and their tuffs.	
	Lower and Middle			Red porphyries	Interbedded red quartz porphyry and albitophyres with their pyroclastic derivations.		Interbedded, distinctively-colored albitophyres, albite porphyries, quartz porphyries and their pyroclastic derivatives.
				Albitophyres and their tuffs	Interbedded albitophyres, quartz porphyries, albite porphyries with their pyroclastic derivatives.		

A large part of the sequence consists of conglomerate, sandstone of varied coarseness, siltstone, tufa sandstone as well as albite lava, and porphyritic rocks. All these formations are frequently interlaminated and replace one another laterally. The variation in concretions from section to section is especially noticeable in these sedimentary and volcanic rocks.

This variegated formation is believed to be of Franconian age and, on the basis of the following data, may represent the bottom of the Famennian stage:

a) The author has collected remains of Heleniella cf Theodori Zal. and Lepidodendron rhombicum Daws, classified by M.F. Neuburg, and in his opinion an Upper Devonian index fossil.

b) Ascending the section, the variegated formation is replaced by a series of carbonate rocks, at the base of which fossils characteristic of the Sulzifer layers of the Famennian stage of the Upper Devonian were collected. The thickness of the variegated formation is not uniform and ranges, within the syncline, from 0 to 800 m.

3. D_3^2 - C_1. In the Dzhail'ma syncline, a single series of fragmented carbonate rocks, in which we note no marked unconformity or diastem indicating breaks in the sedimentary record corresponds to the Famennian, Tournaisian and Visean stages.

The contact separating the series of fragmented carbonate rocks from underlying formations is extremely well-defined and there are no indications of any gradational contact. Transgressive Famennian deposits on different levels of the variegated formation and, occasionally, on extrusive rocks of the Lower and Middle Devonian, are common.

The separation of stages and of other lesser stratigraphic units in this series is based on paleontologic data. Because this subject has been previously studied in detail [10] we shall not dwell on it in this article. The thickness of the series is 1400 to 1800 m.

The Famennian stage deposits within the Dzhail'ma syncline are not uniform in composition; it is possible to separate at least three separate sections on the basis of lithologic characteristics.

1. Deposits of the first type are extensive across the western limb of the syncline. Good sections are known to exist in the region of the Kula mountains, south of the Karashoko ridge, in the region of the Taskuduk and Akkuduk wells, along the bed of the Espa River and in a number of other localities (Fig. 1). They are represented by massive, homogeneous limestone beds containing a rich fauna of brachiopods, corals and crinoids and are, as a rule, devoid of any admixed clastic material. The fauna is typical of the Sulzifer layers of the Famennian stage. Thickness is 400 to 500 m.

2. Deposits of the second type are developed in the eastern limb of the syncline around Atasuy and in the nearby Zhilandinsk syncline. In these regions the limestone is interbedded with irregularly-grained and poorly-bedded sandstone and is frequently enriched by fragmental material. In addition, several seams of dolomite have been discovered among the Famennian deposits of the Zhilandinsk syncline. The faunal complex is identical to that found among the deposits of the first type. Thickness is 400 to 500 m.

3. Deposits of the third type are of local distribution. The most representative section of these deposits was observed in the region of the Karadzhal ferromanganese occurrence (northern limb of the syncline). Here, a sequence of thin and microgranular rock of siliceous, argillaceous-carbonate composition, commonly enriched by an admixture of finely pulverized organic matter, corresponds to the Famennian stage. Seams and lenses of siliceous and jasperoid rock, effusives and tuff, as well as layers of ferromanganese ores (hematite, magnetite, manganese oxide, and manganese silicate and oxide ores) are present in the upper part of this formation. These ore minerals are similar to those of the lower portion of the productive block of the Karadzhal occurrences. In the formation described, fossils are rare. They are pelecypods and cephalopods, among which, forms characteristic of the Upper Devonian have been discovered. Ostracods are equally extensive as well as organisms with a siliceous skeleton, e.g., radiolaria.

One of the distinctive peculiarities of siliceous, argillaceous-carbonate rock is the inherent diversity of its texture and minor structures. In addition to the laminated varieties, layers of interrupted lamination or of spotted and lumpy structure are fairly widespread. These features are obviously the result of a diagenetic redistribution of sedimentary material. The numerous concretions in the deposits described are similarly attributable to diagenetic processes. Let us now review these formations in some detail.

A number of research workers (I.V. Dyugayev, V.I. Kavun, M.E. Kerenskiy and others) described the seams of "conglomerate-like" rock and fine-shingle conglomerate of the beds lying immediately beneath the Karajal ore deposit. The presence of these

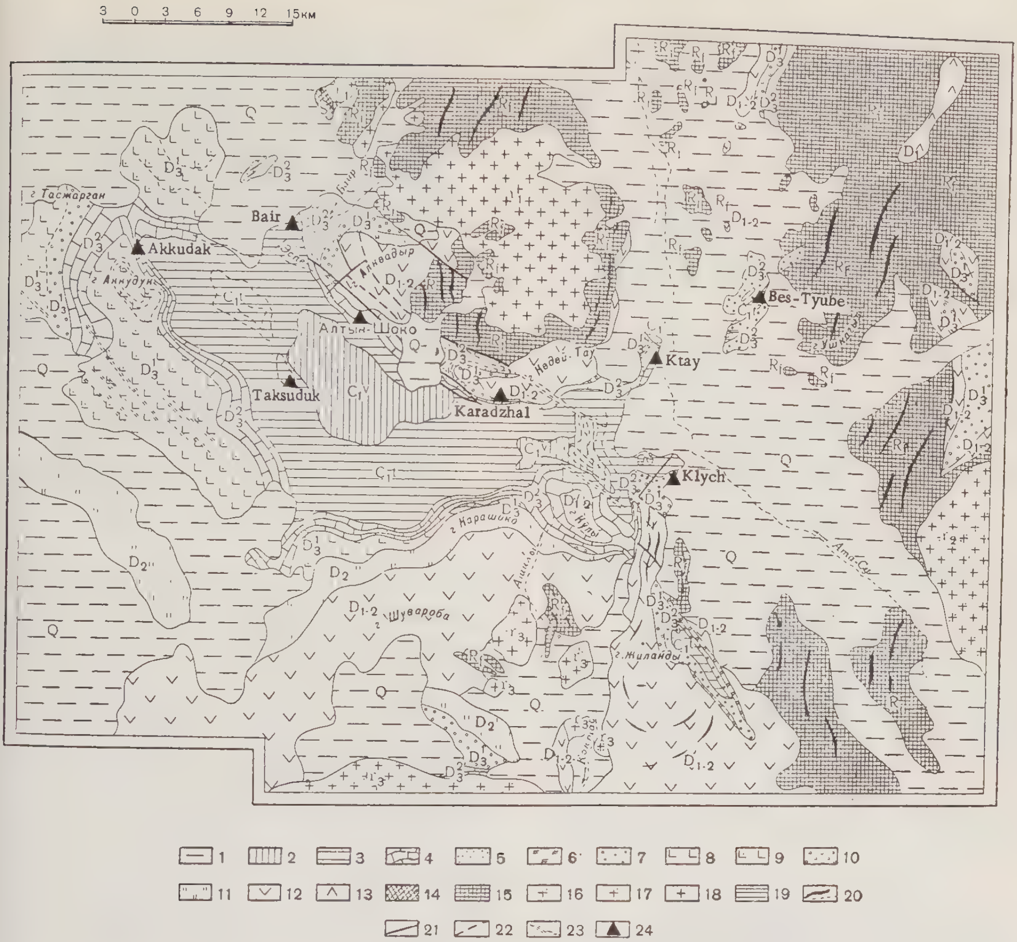

Fig. 1. Geologic Map of the Dzhall'ma Syncline:

Quaternary Deposits. 1. Argillaceous soil, sandy loam.

Lower Carboniferous, Visean Stage. C_{1v} 2. Sandstone, siltstone, limestone.

Lower Carboniferous, Tournaisian Stage. C_1^t 3. Reef limestone, siliceous argillaceous carbonate rock, marl. Tuffite, ash tufa.

Upper Devonian, Famennian Stage. D_3^2 4. Reef limestone; 5. Siliceous argillaceous carbonate rock, solitic limestone with tuff of basic effusives; 6. Siliceous argillaceous limestone with spilite-like effusives and tuff and lenses of jasperoid rock in the upper part of the profile; 7. Sandstone, sandy limestone, siltstone, limestone.

Upper Devonian, Franconian Stage. D_3^1 8. Interbedded albitophyre, porphyrite and tuff, subordinate sandstone and conglomerate; 9. Interbedded albitophyre, porphyry, porphyrite and tuff with sandstone and conglomerate; 10. Red-brown sandstone with lenses and beds of conglomerate, subordinate acid lava.

Middle Devonian. D_2. 11. Red porphyry and tuff.

Lower and Middle Devonian. D_{1-2}. 12. Albitophyre and tuff.

Lower Devonian. D_1. 13. Diabasic porphyry and tuff. Silurian; S; 14. Sandstone. Tufa-Sandstone, argillaceous schist, diabasic porphyry. Riffeian; Rf; 15. Quartzite and jasper. 16. Granite, Y3. 17. Hercynian granite, Y2. 18. Middle Devonian granite, Y1. 19. Veins of gabbro-diabase and diorite-porphyry, δ ; 20. Strike. 21. Fractures accompanied by displacement of strata. 22. Fractures with no visible displacement of strata. 23. Zones of crushing accompanied by development of quartz veins. 24. Outcrops of iron-manganese ores.

seams was regarded as indicating that the whole layer was formed under shallow-water conditions and that the deposition of the ore was preceded by shoaling and an erosion of the basin.

Research work has established, however, that the "conglomerates" are, in fact, common, finely granulated siliceous, argillaceous limestone, containing numerous concretions of diagenetic origin, formerly erroneously termed shingle.

The growth of these concretions was, probably, facilitated by the increased organic content in the sediments (an average of 5 percent). The size of the concretions is variable and ranges from several millimeters to 3 cm., in some instances reaching 5 cm.

The composition of the concretions is approximately the same as that of their containing mass (siliceous, argillaceous limestone), the usual difference being a comparative reduction of carbonaceous and argillaceous material with a corresponding increase in silica and carbonate content. Concentric structure is distinctive of many concretions, a condition produced by the alternation of the mineral content from the center of the concretion to its periphery (alternation of silica and carbonate layers with or without an admixture of argillaceous material (Fig. 2).

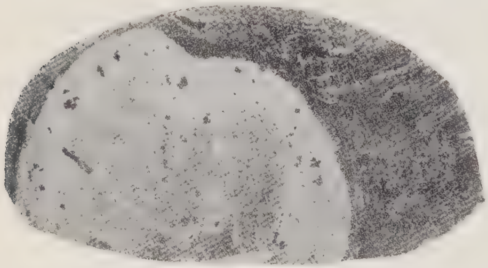

Fig. 2. A siliceous carbonate concretion in siliceous limestone. Mag. 5. Nicol's prism parallel.

The concentric structure of the concretion is particularly noticeable where individual surfaces have been subjected to crystallization and coating by iron oxide.

The outer limits of the concretions are far from sharp and distinct. On the contrary, a perfectly gradual transition from the peripheral covering of a concretion to the mass of the ore in which it is contained is common.

The manner in which laminae flow over the concretions is demonstrated in samples of transparent, polished sections (Fig. 3).

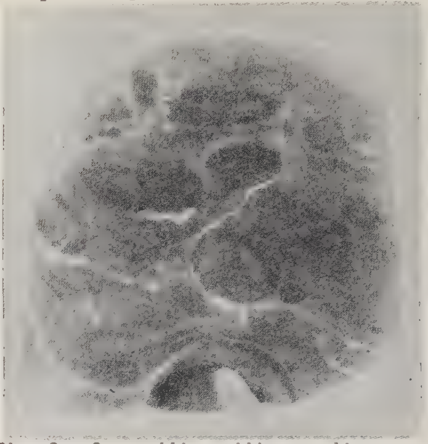

Fig. 3. Crystalline siliceous limestone with siliceous carbonate concretions. Natural size.

The evidence stated above: the concordant, laminated covering of the samples described, their concentric structure, the similarity of their composition to that of the containing mass and, lastly, the fluidity of the line separating them, point to the fact that these are diagenetic concretions and not shingle, as was maintained by previous investigators. It therefore follows that there is no reason to assume that the bed was deposited under conditions of shoaling accompanied by erosion. On the contrary, the microgranulation of the ores, the absence of detrital material in them, as well as the fine, horizontal lamination point to the possibility of sedimentation in relatively deep parts of the basin.

As previously mentioned, the upper Famennian siliceous limestone beds in the region of the Karadzhal ore body are characterized by seams and lenses of siliceous, jasperoid rock, of extrusive rocks and tufa, as well as bodies of ferromanganese ores.

Because of the fact that we were the first to recognize extrusive rocks at this locality and that some geologists still do not wish to admit their existence here, we shall describe them at some length.[1]

Seams of extrusive rocks and tufa were discovered on the western flank of the ore body.

The profile of the upper part of a

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[1] In studying and describing extrusive and tuffaceous rocks, the author consistently consulted V. S. Koptev-Dvornikov, M. S. Nagibina and V. N. Razumova, to whom she wishes to express her deep gratitude.

Famennian bed along borehole 191 is an example (from the bottom up):

1) A block of dark grey, fine-grained, argillaceous limestone, the laminae of which are enriched by admixture of detrital material of siltstone size, interlaminated with thin-bedded argillaceous limestone. Apparent thickness, 29 m.

2) Spilitic-type extrusives. Compact, greyish green rock with a pronounced amygdaloidal texture. The amygdules make up 15 to 20 percent of the total mass. The rock, composed of calcite and chlorite, is measured in fractions of a centimeter; 11 m. thick.

3) A block of extrusives similar to 2, interlaminated with agglomerated tufa of the same composition.

The agglomerated tuff is a massive, compact rock, greenish grey, of well-defined, roughly fragmental texture. The fragments are from a few millimeters to 5 cm in diameter. The shapes of the fragments tend to be more angular than fused. Most of the fragments are of extrusives similar to those which are interbedded in the main mass of rock and some sedimentary rocks of argillaceous-carbonate and siliceous carbonate composition. Large fragments are cemented together by a finely-granulated mass of identical composition but consisting of splinters, measured in fractions of a millimeter. The finely-fragmented mass of the rock is commonly strongly calcitized. The overall thickness of the block is 12 m.

4) Carbonaceous limestone, black, microgranular to microcrystalline, thinly laminated; certain seams pyritized. 5 m thick.

5) A block of extrusives, similar to seam 2, interlaminated by fragmented tuff of the same composition; 7 m thick.

6) Carbonaceous limestone, similar to seam 4; 7.5 m thick.

7) Agglomerated tuff, similar to that described in seam 2; 2 m thick.

8) Brecciated lava, of the spilite type. Greenish grey; plainly discernible fragmental structure, the fragments differing in the degree of decrystallization of the lava. Their size does not exceed 2 cm; edges are fused; 1.5 m thick.

9) Limestone, microgranular; dark grey; 0.3 m thick.

10) An extrusive rock of the spilite type; 0.2 m thick.

11) A finely-fragmented tuff, similar to layer 5; 0.15 m thick.

12) Carbonaceous limestone, similar to layer 6; 0.1 m thick.

13) An extrusive rock of the spilite type; 0.3 m thick.

14) Carbonaceous limestone, microgranular; 9 m thick.

15) Agglomerated tuff, similar to layer 3; 2 m thick.

16) Limestone, dark grey, microgranular, with an original, spotted coloring, caused by nonuniform distribution of finely pulverized carbonaceous matter; 12 m thick.

17) Siliceous argillaceous limestone, enriched by an admixture of organic matter; originally intermittent lamination; 27 m thick.

18) Siliceous, argillaceous limestone pigmented by a carbonaceous substance, microgranular to microcrystalline. In the upper part, the rock is violet red, because of increased ferric content. Thin seams of jasper and iron ore are also present. Thickness 80 to 90 m.

There is an almost total absence of porphyritic rock in the feebly decrystallized main mass. It is possible to distinguish several rock types on the basis of degree of crystallization:

1. Extrusive rock composed of numerous irregularly-distributed, elongate baths of albite. The space between the laths are filled in by an aggregate of secondary minerals, mostly chlorite, which forms the matrix together with volcanic glass and small grains of dark-colored minerals. Small, irregularly-shaped grains of titanomagnetite are scattered through the chlorite. In several instances, the plagioclase laths and small amygdules were stretched in the same direction. The quantitative ratio between the plagioclase laths and the chloritized glass by which they are cemented together changes within fairly wide limits, the laths in places amounting to as much as 60 percent of the total rock mass and, at other places, only 20 to 25 percent (hyalopilitic structure and almond-shaped grains) (Fig. 4).

2. Extrusive rock consisting of a matted aggregate of extremely fine microliths of plagioclase, saturated by completely chloritized glass. As a general rule, the microliths are irregularly orientated, but microliths stretched plastically are less common. (Pilotaxitic structure and almond-shaped grains) (Fig. 5).

Table 2

Mineralogic composition of extrusives

Main Minerals		Secondary Minerals	
Primary	Secondary	Primary	Secondary
-----	Albite	Titanomagnetite	Leucoxene
-----	Chlorite	Hematite	Calcite
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Fig. 4. Extrusive rock of spilite type with hidden hyalopilitic structure. Mag. 46. Nicol's prism parallel.

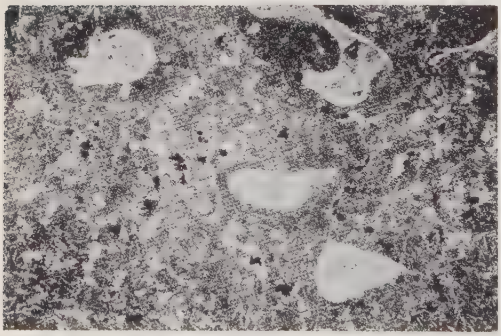

Fig. 5. Extrusive rock of spilite type with hidden pilotaxitic structure and almond texture. Mag. 20. Nicol's prism in parallel.

3. Extrusive rock, consisting of brown, iron-bearing vitreous basic mass, completely replaced by extremely fine aggregates of secondary minerals in which numerous amygdules, filled with calcite and chlorite, are scattered. (Vitrophyric structure and almond-shaped grains. Fig. 6).

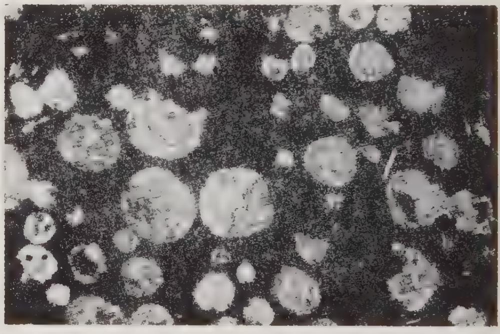

Fig. 6. Spilite type, extrusive rock with hidden vitrophyric structure and almond-shaped grains. Mag. 46. Nicol's prism in parallel.

4. In some extrusive rocks a hidden hyalopilitic or vitrophyric mass contains porphyritic blocks of plagioclase, in places 1.2 to 1.5 mm in length and 1 mm broad, thus giving the rock a porphyry-like texture. Such varieties of rock are not typical.

The extrusive rock described is so extensively transformed that it is possible to determine its original composition only by indirect evidence. The nature of transformation of the vitreous mass and the texture of the rock indicate its basic composition. The fact that the outflow of lava was of a submarine type and that the particles of plagioclase within the rock are totally albitized indicate a spilitic origin. Its general structure and typical amygdaloidal texture do not contradict this assumption.

On the other hand, some varieties contain blocks of porphyritic plagioclase.

Although this porphyritic plagioclase is rare, its presence does not permit identification of the extrusives described as typical spilites. In addition, in typical spilites the albite lath is somewhat fresher in appearance than in the extrusive rock we have studied. However, taking into account all the considerations mentioned above we must conclude that the rock described is a basic extrusive of a spilitic type.

Formerly, research workers have maintained that this rock is hypabyssal and not extrusive, and have described the conformable bedding of volcanic and sedimentary rocks and the frequent interlamination as lit-par-lit injections of magma; i.e., the blanket deposits of extrusive rock were described as extremely thin interbedded intrusive bodies. This point of view is contradicted by fact, and the classification of the rock as extrusive is sustained by the following features:

1. Interlamination of lava with tufa of the same composition.

2. Structural and textural peculiarities of the rock, the details of which have been previously enumerated.

3. Absence of a sharp contact between the lava and the sedimentary formations.

Undoubtedly, veined rocks of apparently pre-Visean age are common in the Karadzhal region. However, they cannot be identified with the extrusive formations previously mentioned, because they differ from them by their stratification and manner of contact with the country rock and by their composition and the degree of their decrystallization.

The thickness of the Famennian deposits in the Karadzhal region is 200 to 250 m.

Higher in the section, the Famennian deposits are gradually replaced by Lower Carboniferous beds. In essence, a single bed corresponds to the Famennian and Tournaisian stages, and the criterion employed for subdividing this bed into various stages is exclusively faunal. Thus, as far as one is able to judge by exposures, a crust of mainly carbonate rock continued to form over the major part of the syncline during the Tournaisian age.[1] In the Lower Tournaisian, massive reef limestone, hardly differing from that of the Famennian, is predominant. In these beds, lenses and layers of siliceous and silicified limestone and, less commonly, laminae of siliceous shale, marl and calcarenite are common. There is a rich fauna of brachiopods, corals, cephalopods and crinoids.

In the Upper Tournaisian, the limestone is argillaceous and siliceous, and to some extent approximates marl.

In the Karadzhal region the deposits are essentially different. Here, the Tournaisian is represented by a crust of siliceous, argillaceous carbonate and a siliceous-jasperoid rock, tuff and ash beds, including subordinate limestone layers. The main formation containing the Karadzhal ore body occurs at the base of this crust.

Some of our predecessors (I. V. Dyugayev, V.I. Kavun, M. E. Kerenskiy and others) held that the Tournaisian deposits in the Karadzhal region are represented largely by limestone. Thus, blocks of carbonaceous and ash-gray limestone, several hundred meters thick, were cited. Analyses have proved that as a general rule, the carbonate content of this "limestone" does not exceed 25 percent and, in many cases, only reaches 9 percent; consequently, these formations cannot by any means be regarded as limestone. Further research has shown that we are dealing with a lithologically-varied complex of deposits mainly composed of micro-granular, siliceous, argillaceous limestone, close to the Famennian stage tuffite and ash tuff. Among the formations mentioned, pure limestone is present only in interbeds of subordinate thickness. For quite some time these formations were erroneously believed to be normal sedimentary rocks, such as siliceous and argillaceous limestone, siltstone, siliceous shale, etc. and their true origin was determined only after meticulous microscopic research.

Ash tuffs (Figs. 7 and 8) consist of 90 percent extremely fine ash material by which individual, larger (0.01 to 0.05 mm) fragments of volcanic glass and individual grains of quartz and plagioclase are cemented together. The ash and the fragments of volcanic glass are wholly replaced by a fine-grained aggregate of secondary minerals, mainly chlorite, silica and sericite. Montmorillonite very commonly develops over the surface.

The tuffaceous character of the rock is easily discernible in relict fragments of volcanic glass, usually distinctly sickle- and fork-shaped (Figs. 7 and 8).

The fragments of quartz and plagioclase are also angular and are devoid of any traces of rounding, a fact which suggests a pyroclastic origin.

[1] We are here dealing, primarily, with the western part of the syncline. In the eastern part the carboniferous deposits are so barely exposed that any description, be it ever so general, is, at the present, difficult.

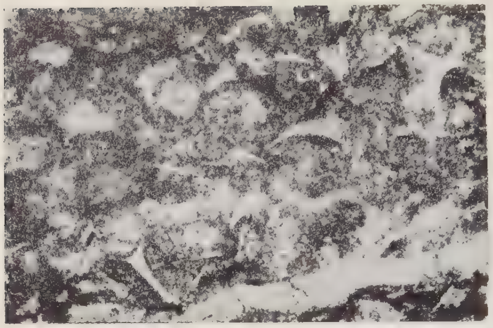

Fig. 7. Ash tuff.
Mag. 90. Nicol's prism in parallel.

The tuffites are of the same composition and origin as the tufa, described above, but contain few products of volcanic eruption. These volcanic products appear to be distributed with normal sedimentary material, commonly silica and carbonate which were deposited at the same time as the ash particles. The ratio between pyroclastic and normal sedimentary material in the rock is not uniform and differs widely from layer tr layer, a fact which explains the laminated texture common to the tuffites.

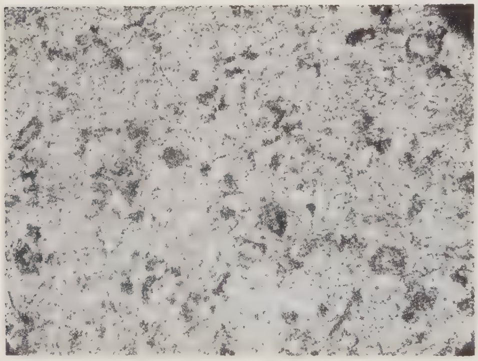

Fig. 8. Ash tuff.
Mag. 90. Nicol's prism in parallel.

In predominantly siliceous interlayers numerous relics of radiolaria are commonly present. In places, small crystals of plagioclase, tourmaline and splinters of quartz grains, all devoid of any traces of rounding, are common (Fig. 9).

Profile of Tournaisian deposits in the region of the Karadzhal ore body along borehole 112 (from bottom to top):

1. Higher in the section, an ore-bearing layer is gradually displaced by fine-grained, reddish-grey ferromanganiferous, siliceous, carbonate rock.

2. Fine-grained argillaceous limestone, dark grey; homogeneous, massive, laminated and brecciated in places in the lower part; 42 m thick.

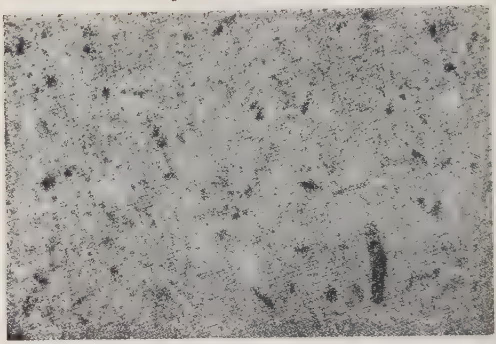

Fig. 9. Tuffite.
1. Fragment of plagioclase crystal.
2. Fragment of tourmaline crystal.
3. Fragment of quartz.
Mag. 90. Nicol's prism in parallel.

3. Microgranular argillaceous limestone, rich in carbonaceous matter. Black in color, in places laminated and strongly pyritized; 80 m thick.

4. Breccia (tectonic?) of average and small-sized fragments. The fragments are generally siliceous, argillaceous limestone. The breccia range in size from a few millimeters to 4 cm. The cementing material is a crystal aggregate of quartz-albite-calcite, or prehnite-calcite; 30 m thick.

5. Finely granulated siliceous, argillaceous limestone, dark grey, penetrated by a network of calcite and quartz-albite streaks. In some sectors the rock is very broken; 50 m thick.

6. Light, quartzose rock; 28 m thick.

7. A block of microgranular siliceous limestone; possesses an extremely distinct, spotted texture, because of the diagenetic redistribution of material within it; 32 m thick.

8. Fine and microgranular siliceous, argillaceous limestone,. interlaminated by tuffite and ash-tufa. Macroscopically extremely homogeneous; dark grey and in places laminated; 78 m thick.

9. Siliceous tuffite, green or greenish grey; massive with a conchoidal fracture;

40 m thick.

10. Siliceous, argillaceous limestone; microgranular, dark grey; 5 m thick.

11. Breccia, similar to that of layer 10. The size of the fragments does not exceed 3 cm. The cementing material is calcite; 60 m thick.

12. Sedimentary rock, similar to that of layer 10, with a somewhat larger silica content in the upper parts (Silica content exceeds 50 percent). The thickness of the interbed of organic, crystalline limestone is 0.15 m. The overall thickness of the layer is 130 m.

13. A block of micro- and fine-grained siliceous limestone, in places containing an admixture of tuffaceous material, interlaminated with light-colored silica and quartzose rock; 20 m thick.

14. Quartzite; micro-crystalline, light grey to grey; 9 m thick.

15. Siliceous tuffite. Cryptoclastic texture, green or light green, compact, homogeneous and having a conchoidal fracture, or thinly laminated, splitting into sharp-angled flakes; 25 m thick.

16. Siliceous tuffite, mauvish-grey. Compact with ill-defined bedding. Conchoidal fracturing. 8 m thick.

17. Greenish-grey and pinkish-grey interbedded siliceous tuffite; 24 m thick.

18. Siliceous rock, microgranular, light grey; 28 m thick.

The thickness of the Tournaisian deposit is 750 to 800 m.

Visean deposits are related by a gradational contact with the deposits beneath them. They are chiefly grey, terrigenous, sandstone, siltstone, argillite, among which, and subordinate argillaceous limestone, mainly present in the lower part.

A comparative study of sections of the carbonate-fragmental series in different parts of the Dzhail'ma syncline brings us to the conclusion that sedimentation conditions were not uniform over the whole area of the syncline.

1. In the western limb of the syncline, with its reef-like limestone, devoid of admixtures of terrigenous material and containing a rich marine fauna, there apparently existed a shallow, open, marine basin of normal salinity during the Famennian and Early Tournaisian.

2. In the eastern limb of the Dzhail'ma syncline and the Zhilandinsk syncline a bed of limestone, containing an admixture of terrigenous material, is interbedded with poorly-separated and variously-granulated sandstone and corresponds to the Famennian stage. It is obvious that such deposits were formed in areas adjacent to the shoreline of the basin.

3. Lastly, in the northern part of the syncline, in the region of the Karadzhal ore body, deposits of a totally different kind were formed during the Famennian and Tournaisian ages. Thin, finely granular siliceous, and argillaceous carbonate rock, tuffite, ash tufa, in places extrusives of effusions and their pyroclastic derivatives paragenetically related to strata and lenses of ferromanganese ores are constantly present in these deposits. It is apparent that the formative conditions of a rock complex of this kind must have differed radically from conditions in other parts of the syncline. In our opinion, their specific traits are as follows:

A. The accumulation of fine-grained sediments with no admixture of fragmental material, occurred in relatively deep parts of the basin which, possibly, corresponded to areas of inter-reef subsidence. In these areas stable conditions must have prevailed, unfavorable to the development of a normal marine fauna. It is even likely that the subsidence of the basin's floor was not always compensated by sedimentation. (Note the reduced thickness of Famennian deposits in the Karadzhal region.)

B. Sedimentation was accompanied by submarine volcanic activity, not invariably by an outflow of lava and pyroclastic ejection, but sometimes eruptions of a fumarolic nature. It appears that this fumarolic rather than extrusive form of volcanism was predominant. It is this particular type of volcanism which was responsible for the addition of abundant silica to the basin, silica that served as the initial material in forming the majority of the siliceous rocks during the Famennian and Tournaisian ages.[1]

During the Visean period, mainly regressive terrigenous sediments accumulated over the whole expanse of the syncline.

In conclusion, let us briefly examine the genesis of the ferromanganese ore of the

[1] Some varieties of siliceous rock were formed by the metasomatic replacement of various rock-forming minerals by silica.

Karadzhal ore body in view of the close paragenetic link which exists between the ore and deposits of a third kind. The Karadzhal occurrence belongs to the so-called Atasuy group of ferromanganese occurrences of Central Kazakhstan and is the principal one. Apart from Karadzhal, this group includes a series of smaller occurrences and ore-bodies: Ktay, Klych, Kentyube, Bestyube and others (see Table 1).

The primary sedimentary origin of the ferromanganese ore bodies of the Atasuy group is convincingly proved by the works of A.G. Betekhtin, G.S. Momdzhi, I.V. Dyugayev, S.I. Chaykin and others and is unreservedly accepted by the majority of investigators of Central Kazakhstan. The debatable point is the source of the original material which went in to the formation of the sedimentary ores. Here we are confronted by two theories, one which, briefly stated, maintains that the coincidence of material necessary for the formation of iron and manganese ores was brought about by continental waters flowing from the land into the basins [2, 3, 12] and the other, which holds the view that the most probable sources of iron, manganese, and silica were the hydrothermal and fumarolic volcanic products, which were deposited in the basin [13, 14]. Neither of these theories can be accepted as fully proved, yet in the light of the data at our disposal, the second theory on the extrusive and sedimentary origin of the ores, appears to us to be better founded. Let us try to analyze the factual material.

The majority of the ore-bodies of the region are related to definite stratigraphic levels of the Upper Famennian and Lower Tournaisian stages. The period of ore deposition possesses two basic characteristics: first, marine transgression, which began during the Famennian period, reached a maximum at this time and, second, volcanic activity increased along the line separating the Devonian and the Carboniferous beds. In other words, the deposition of ore was taking place at a time during which the existence of considerable areas of land large enough to provide for the outflow of sufficient iron and manganese to form sedimentary ore bodies is improbable.

Further, had the formation of ferromanganese ore bodies resulted from flows of ore-forming materials from the land it would be logical to expect the ore concentrations at the base of the marine transgressive series; in the Dzhail'ma syncline, for instance, at the base of the Famennian beds, and in regions farther south, like Bet-Pak-Dala, in the lower beds of the Carboniferous. However, this phenomenon is nowhere observed. On the contrary, all known ore concentrations occur in the middle of an uninterrupted marine sequence and never at its base.

Lastly, one is entitled to suppose that the origin of ore concentrations is related to local risings and shoalings of the basin, which must have taken place even during maximum transgression of the sea. It has, in fact, been determined that isolated areas of land rose above sea level during the Famennian period, i.e., at a time immediately preceding that of the deposition of the ore. The Zhilandinsk syncline and the eastern limb of the Dzhail'ma syncline, in particular, were undoubtedly situated in the immediate vicinity of the shoreline; nevertheless in the Zhilandinsk syncline signs of ferromanganese mineralization are totally absent and, in the Dzhail'ma syncline, they are quite unrelated to the supposed location of this line.

We, therefore, have no grounds for assuming that the outflow of ore-forming materials moved from the land into the basin.

In addition to the considerations enumerated above, which contradict the validity of the first theory on the origin of the ores, there are, in our opinion, a number of facts which uphold the second theory based on an extrusive-sedimentary origin.

First of all, the period of ore deposition coincides with a general increase of volcanic activity in many parts of Central Kazakhstan.

Next, the paragenesis of these ores with rock of siliceous and volcanic origin points to a relationship between them and the volcanic activity. The close relationship between rock of volcanic and siliceous origin suggests that it is conditioned by submarine volcanic activity, and we know that ferromanganese ore is, as a general rule, associated with siliceous rock. Conformity to this rule is further accentuated by the fact that rock of siliceous and volcanic origin occurs exclusively within areas of ore occurrences and is totally absent in sequences of contemporary strata, lying outside the ore fields.

The close paragenetic relation between ferromanganese ores and rock of siliceous and volcanic origin is not satisfactorily explained by the first of the two theories we are examining.

Lastly, the majority of ore bodies in the region described, including the largest Karadzhal ferromanganese occurrence, coincide with zones of tectonic disturbances. This coincidence should not be taken to mean that the ores fill in tectonic fractures or that they are strictly related to fractures. On the contrary, they occur naturally in

strata, are deposited together with their host rock and correspond to definite stratigraphic units. Nevertheless, the relationship of the occurrences to the tectonic zone is manifest and cannot be attributed simply to chance. In all likelihood, the faults in this zone with their long history of development were certainly in existence at the time of mineralization, and probably served as channels for conveying ore-bearing solutions.

Now let us examine further the changes occurring in the Upper Devonian and Lower Carboniferous strata away from the Atasuy iron-ore region and the type of deposits connected with ferromanganese mineralization beyond this region.

The end of the Devonian and the beginning of the Carboniferous were marked over large areas of Central Kazakhstan by a renewal of volcanic activity of varied intensity in different regions.

According to our own observations and that of other investigators [1, 4, 5, 6, 7, 8, 9, 13] the nature of the Devonian and Lower Carboniferous deposits changes from east to west regularly (from the Balkhash region to the Sarysu-Teniz watershed) and in conformity to a rule.

The main volcanic foci of that period were located in the east, where numerous interlayers of extrusive rock appear among Famennian deposits and where the Lower Carboniferous corresponds to a dense and very thick extrusive stratum. Farther to the west this volcanic activity gradually abated. Thus, in the Uspensk and partly in the Atasuy regions, the peripheral zone of the main volcanic area, the upper part of the Famennian stage is represented by an extremely lithologically varied series largely consisting of siliceous shale, tuffite and ash tufa, interbedded with normal sediments. Still farther to the west, within the Sarysu-Teniz watershed, a relatively uniform stratum, composed mainly of carbonate rock of average silica content, occurs at the bottom of the Carboniferous, corresponding to the Famennian and Tournaisian stages. In common with other investigators, we agree that the siliceous nature of the Lower Tournaisian limestone is related to the volcanic activity of the period.

Thus, it is possible to define three zones in the Devonian and Carboniferous deposits of varied kinds. The first zone corresponds to the Balkhash region, the second to the Uspensk region and the third to the Sarysu-Teniz watershed. No sharp dividing line exists between these zones, and the transition from one to the other is quite gradual. This is abundantly illustrated in the Atasuy region and the Dzhail'ma syncline. Over a major part of the syncline during the Famennian and Tournaisian periods, strata, analogous to those developed in the Sarysu-Teniz watershed, were formed, whereas deposits of the Uspensk sedimentary volcanic type are spread over separate, insignificant areas. (Region of the Karadzhal ore body.)

We also notice in the region described that the vast majority of existing exposures of ferromanganese ore bodies correspond to the Uspensk and Atasuy regions and that the peculiarities of disposition of ore concentrations, which were noted in the southern part of the Atasuy region, remain unaltered in the Uspensk region. It therefore follows that these ores are paragenetically linked to siliceous and volcanic rocks, coincide with definite stratigraphic units which are contemporaneous with sharp increase in volcanic activity and, lastly, are related to fracture zones.

The assumption that there is a direct connection between ore concentrations and volcanic activity is further justified by the fact that all the manifestations described above in the Atasuy and Uspensk regions occupy a definite place in the volcanic and siliceous formations. These formations were distinguished by N.S. Shatskiy [13] from deposits of the Famennian and Tournaisian period of Central Kazakhstan; they correspond to the siliceous shale formations of this series. Thus, the concentrations of iron and manganese in the area of Tournaisian and Famennian rocks of Central Kazakhstan are located in the peripheral zone of the main volcanic region of that period.

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CHANGE IN THE ISOTOPE COMPOSITION OF LEAD DURING SEPARATION FROM NATURAL MINERALS

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ABSTRACT

The possibility of change in the ratio of radioactive and stable isotopes of lead during the transition from the solid phase in natural minerals to dissolved phase in solution is the topic of this article. The ratio of individual isotopes, according to the authors, is apt to change as much as ten times.

The change in the isotopic content of lead during its separation from minerals should be accounted for during the study of the behavior of lead in geologic processes.

* * * * *

INTRODUCTION

A large number of geochemical works are devoted to investigation of the isotopic content of lead in nature. Three stable isotopes of lead are the final product of disintegration of the radioactive series, and the determination of ratios of isotopes is necessary before determining the absolute age of geologic formations.

The investigation of the isotope content in nonradiogenic lead ore permits us to determine, besides other things, the path of migration of lead in nature and to clarify many problems of ore genesis. In several cases, it is possible to prove that in one ore deposit there are different varieties of lead which may be differentiated from each other by the ratio of isotopes, and are different in origin [1].

During investigation of this very important geologic problem it is necessary to note how susceptible the isotope content of lead is to change during isolation from the solid phase -- minerals -- to the liquid phase -- natural solution. Such changes are of wide interest because of the radioactive elements. This is related to the fact that the products of disintegration -- atoms, which have suffered radioactive loss -- could occupy a different position in respect to the zone of deformation and microfissures of the crystalline lattice of minerals in comparison with the atoms of the matrix material; and in general they are easily isolated in outside materials. The change of isotopic content of uranium, thorium, radium, and other elements, has been observed in laboratory experiments during the leaching of radioactive elements, and this process has also been observed in natural conditions. The isotopic content of elements in natural waters and secondary minerals can be sharply different from that content which corresponds to equilibrium conditions, characteristic of the radioactive elements of ancient primary minerals. The basic principles are reduced to the following [5]:

1. The products of disintegration are isolated from the minerals in greater degree than their isotopes -- the ancestors of radioactive families; meanwhile the short-living isotopes are fractionated to a relatively higher degree than long-living isotopes.

2. Products of the disintegration sequence which are subordinate in quantity in the material are isolated to a higher degree. This is probably related to the fact that the ancestor of the radioactive series -- the subordinate component -- enters a crystalline lattice with less attraction than the main radioactive isotope of the mineral.

The study of the fractionation of isotopes

and their separation in the process of migration of lead is of great practical importance. It is necessary to note that the lead method for determination of absolute age is the best of contemporary methods in geochronology; however, it commonly causes a discrepancy in the age obtained because of the ratio of different isotopes. Undoubtedly, this is due to the processes of migration of radioactive elements and lead; however, the details of the process are not yet sufficiently clear. In recent years the determination of the age of certain secondary minerals, which take lead during their formation from primary radioactive minerals, appeared in the literature. These investigations, based on the study of the isotope content of lead, do not consider the possibility of the change of the lead content during the separation of lead from its minerals [1].

At present, only isolated indications on the change of the isotope content of lead during such separation are known.

I. Ye. Starik and his co-workers [4] showed that isotopic content of lead from the disintegrated crust of a uraninite crystal ($Pb^{207} = 12.9$, $Pb^{208} = 2.9$, considering $Pb^{206} = 100$) differs from the lead in the central zone ($Pb^{207} = 10.8$; $Pb^{208} = 1.8$ considering $Pb^{206} = 100$) by diminishing the uranium lead content. At the same time, the total lead content in the "crust" relatively increases.

Changes in the ratio of stable isotopes of lead during its separation from sphene was observed by Tilton and his assistants [4]. The results of their investigation are given in Table 1.

From Table 1 it is evident that lead separated from the extracted material approaches in content the average lead of the rock, i. e., the lead of nonradioactive origin but enriched by thorium lead.

Systematic investigations of changes in the ratio of lead isotopes during their extraction are desirable. It is necessary to contemplate separately the behavior of nonradiogenic isotopes of lead, which existed in lead minerals during their formation, the radiogenic isotope as the final product of disintegration of radioactive minerals, and the radioactive isotopes themselves.

We have aimed to investigate changes in the relative content of the radioactive isotope of lead: the products of uranium disintegration -- RaD -- and the products of thorium disintegration -- ThB -- during their isolation from natural minerals, i. e., the specific activity RaD/Pb and ThB/Pb, where Pb is the summary content of lead in the mineral. The content of RaD and ThB is given in milligrams of equivalent quantities of uranium and thorium and Pb in milligrams. Unfortunately, we were unable to determine the isotopic content of the stable isotopes of lead, but qualitative evaluation of the RaD/Pb ratio in certain cases permits correct determination of the presence of nonradiogenic lead in minerals.

Object of investigation. Measurement methods.

We have investigated only moderately active minerals, because the total amount of lead in the measuring apparatus should be, according to our method, not less than 1 mg. Minerals of different types were studied: primarily high-temperature uranium minerals containing lead of radiogenic origin (uraninite), and low-temperature minerals, commonly especially enriched in nonradiogenic lead (pitchblende, and uranium black), thorium minerals (ferrithorite, monazite), secondary or altered minerals, which also contain a large amount of lead ore (wolframite and other minerals). Radiochemical analysis of these minerals is given in Table 2.

Leaching was effected through solutions of

Table 1

Changes of isotope content of stable isotopes of lead during leaching from minerals.

Object from which lead is obtained	Isotope content of lead ($Pb^{204} = 1$)		
	Pb^{206}	Pb^{207}	Pb^{208}
Rock (granite)	20.52	15.65	48.73
Sphene (accessory mineral)	108.6	22.2	146.2
Acid extraction from sphene	21.8	15.7	69.3

Table 2

Radiochemical analysis of minerals.[1]

No.	Description of mineral	Formula	Content, %			Th:U	U:Pb
			U	Th	Pb		
	Uranium minerals						
1	Uraninite, North Karelia	UO_2	52.8	0.04	16.6	0.0008	3.18
2	Uranium ore (pitchblende)	U_3O_8	24.5	0.3	2.2	0.01	11.13
3	Rock, enriched by uranium black (1/5 sample)	U_3O_8	2.08	0.005	0.27	0.002	7.63
4	Same (2/5 sample)	U_3O_8	0.90*	0.001	0.12	0.001	7.50
5	Same. Zone of fractures (6/5 sample)	U O	2.05**	0.006	0.19	0.003	10.78
6	Brannerite	$(U, Ca, Fe,)Ti_2O_6$	33.5	2.72	--	0.09	--
	Thorium minerals						
7	Ferrithorite	$(Fe, Th)SiO_4$	1.9	32.1	0.8	16.9	2.0
8	Monazite	$CePO_4$	0.15	1.4	--	9.3	--
	Secondary and changed minerals						
9	Wolframite, containing secondary radioactive minerals	$(Fe, Mn)WO_4$	0.03	0.021	0.09	0.7	0.33
10	Rock, enriched by secondary mineral of the mica type		1.86	<0.0005	0.97	<0.0003	1.92
11	Decomposed mineral of the oxide type		0.013	0.050	0.62	3.8	0.21
12	Rocks, containing galena and radioactive minerals		0.11	0.005	1.6	0.04	0.69

[1] Uranium and thorium were determined in a majority of cases by the emanation method from radium isotopes. Lead was determined from the RaD/Pb ratio and supposition of equilibrium of the series Ra = Pb. Radioactive equilibrium Ra = U was confirmed for all minerals except the rock enriched by uranium black (enrichment in radium). In the last case the U/Pb ratio was determined from the value RaD/Pb and Ra/U for *Ra/U=0.9 and Ra/U=0.6.

different chemical content (distilled water, hydrochloric acid and nitric acid solutions, sodium solutions, and solutions of ammonium acetate; the latter was used as a reagent for the easy extraction of lead in the form of an acetate compound). The selection of the solution, its concentration, and time for leaching was to a certain degree arbitrary. The most expedient were the application of weakly mineralized solutions, similar to natural water. However, it often happened that the extracted lead was not in sufficient quantity. In certain cases, the lead from solutions was precipitated by addition of an inactive lead-bearer, therefore, only the ratio of radioactive isotopes has been investigated.

If the quantity of extracted lead is comparable to the total lead content in the mineral, then the deep disruption of the mineral was considered, and the isotopic content of lead in the extract under such conditions approaches that observed in the mineral.

Determination of the coefficient of leaching of the lead, i.e., such part of it, which came into solution from suspension, did not interest us as a separate problem; in Table 3 only the data which we have obtained are given. The leaching coefficient for the majority of primary and secondary minerals is several percent. Only the sample of the rock enriched by uranium black, from the zone of fracture, and the disintegrated

oxides showed the longer (up to 47 percent) or almost total (95 percent) isolation of lead from extraction. In fact, the investigated rock from the zone of fracture had shown almost total absence of lead after leaching.

tained with a precision of ±5 percent. The residue was carefully filtered. The filter with the sediments of lead ferrocyanide was prepared for measurement of the radioactive lead isotope. RaD was determined by beta

Table 3

Quantity of lead coming into the solution from the mineral (given in percent of lead in suspension).

Object of investigation	Suspension (2) in gr	Quantity of lead in suspension in mgr	Quantity of leached lead	% of leaching
Uraninite	1,57	260	11	4,2
Repeated extraction	—	260	9	3,5
Control sample	1,93	320	18	5,6
Uranium pitchblende	2,40	53	4,7	8,9
Control sample	30,0	660	20,0	3,3
Rock, enriched by uranium black (1/5)	200,0	560	25,0	4,5
Control sample	150,0	400	5,0	1,3
Same (sample 2/5)	320,0	380	8,0	2,1
Same (sample 6/5)	100,0	19,0	15,0	79,0
Repeated	—	19,0	3,0	16,0
Ferrithorite	50,0	400,0	4,0	1,0
Repeated	—	400	2,0	0,5
Wolframite	150,0	13,5	3,0	2,2
Rock, enriched by secondary mineral of the mica type	100,0	970	10,0	1,0
Control sample	90,0	870	12	1,4
Decomposed mineral of the oxide type	10,0	69	32	46,5
Rock, containing galena and radioactive minerals	80	1280	20	1,5

Note: Comma represents decimal point.

The isolation of lead from minerals as well as from extractions has been done by use of a sulfate. Minerals were dissociated in the presence of H_2SO_4, except ferrithorite, which was melted with potassium bisulfate and treated by HF in the presence of H_2SO_4. The lead sulfate was isolated from the solution from which different impurities were then removed. The separation of Ba and Pb sulfate was done by boiling in ammonium acetate. Lead carbonate was precipitated from the hot solution of lead acetate by adding sodium carbonate. Carbonate was dissolved in weak acetic acid. The quantitative determination of lead in this solution was done by amperometric titration according to a method devised by O. A. Songina [2]. Titration was done by use of potassium ferrocyanide with which lead gives a weakly soluble salt. The lead content can be ob-

radiation of accumulated by-product RaE of a bismuth isotope, and ThB from the beta radiation of this isotope and its short-living products of disintegration. The measurement has been conducted with a counter-type instrument B with a face indicator. The indicator was located in a standard lead housing, in which the preparate was always put in a strictly defined position.

Chemical peculiarities of bismuth permit precipitation of its micro-traces (accumulated during isolation up to the moment of titration) together with lead precipitated by potassium ferrocyanide. For safe determination of RaD it was necessary to plot the curve of RaE accumulation for a period of time equal to 20 to 50 days. The activity has been changing according to the law (1) where RaD and ThB were present in the sample.

$$J_t = i_1 [RaE_0 e^{-\lambda_{RaE} t} + RaD (1 - e^{-\lambda_{RaE} t})] +$$
$$+ i_2 \left[ThB_0 e^{-\lambda_{ThB} t} + (ThC + ThC'' X e^{-\lambda_{ThB} t - \lambda_{ThC} t}) \frac{\lambda_{ThC}}{\lambda_{ThC} - \lambda_{ThB}} \right], \qquad [1]$$

here RaE_0 is the quality of radioactive bis- uth precipitated with lead ferrogyanide, RaD the quantity of isotope in the sample, hB_0 is the amount of ThB at the moment of olation of lead sulfate from the solution atrix, and i_1 and i_2 are the effectiveness of gistration of radiation from RaE and ThB vith the products of disintegration).

Investigating the relationship between ctivity and time, we can with sufficient ecision determine RaB and ThB separately.

Changes in the typical curve of activity for e samples in respect to time are given in igure 1. Besides, we have applied the ethod of absorption of beta radiation by the yer of aluminum for qualitative evaluation. he same method was used for control of ossible impurity from UX_1. As standards, e minerals containing a known amount of and Th were used. The result of the analy- s of radioactive lead has been controlled the addition of inert lead. In our condi- ons, 1 mgr of RaD (in units of uranium) as given an effect of $i_1 = 33.8 \pm 0.9$ $\frac{\text{imp}}{\text{in/mgr}}$ at a change in radiation of RaE. rom 1 mgr of ThB (in the units of balanced h) together with beta-radiating products $= 38.9 \pm 0.9 \frac{\text{imp}}{\text{min/mgr}}$ was also registered.

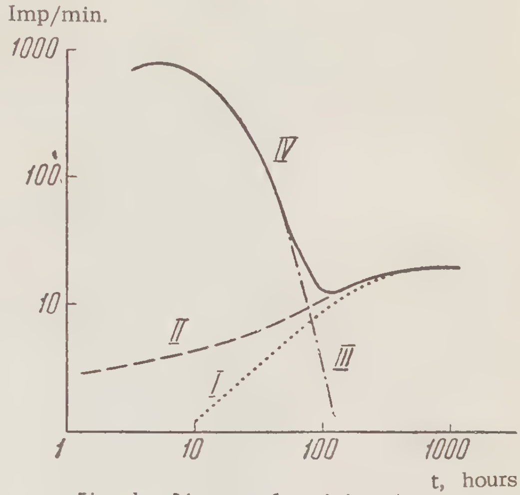

Fig. 1. Diagram of activity changes with time for the sample.

I. Accumulation of RaE from RaD; II. Change in the quality RaE with consideration of initial content of RaE_0; III. The composition of ThB; IV. General curve of activity changes according to Formula 1.

Measurement results

The results of investigation are given in able 4; the description of minerals (Column and the object from which lead was ex- acted (Column II) are also given. For ctractions the medium and duration of aching are indicated. From every object everal samples were obtained, the number which is given in Column III. In the llowing columns the ratio of isotopes RaD, hB, and inactive lead are given. RaD and hB content is given in the units of balanced anium and thorium. The samples contained om 0.8 to 8 mgr of inert lead. The error as calculated as an arithmetic mean from e value of the errors for separate samples, hich include the error on determination of ad at titration and mean quadratic error in ounting impulses during the measurement radioactive isotopes, and also the error om standard counting of impulses. Let us ontemplate the results of investigation for e separate minerals.

URANINITE. Specific activity RaD in uraninite was 3.18 ± 0.30. It is possible to calculate that the RaD:Pb ratio is equal to 3.61 when the content of products for the thorium and actinium series is taken into consideration.

From the expression

$$\frac{Pb^{206}}{U} = \frac{206}{238}(e^{\lambda_U t} - 1) \qquad [2]$$

we have determined the age to be 1,800 million years, which is in good agreement with the age for uraninite of the Belomorskiy formation, accepted by I. Ye. Starik [3].

First extraction from uraninite (20 days, water extraction) contained lead with specific activity equal to 6.12. Lead from the repeated hydrochloric acid extraction possessed considerably lower activity (3.66 ± 0.38). Controlled hydrochloric acid extraction has given a similar value of activity. Probably, the action of a strong agent, hydrochloric acid solution, brings partial solution of minerals, during which the isotopic content of separated lead approaches the lead content of the mineral.

Therefore, during the leaching of lead from uraninite, a considerable enrichment of

Table 4

The results of measurements of radioactive isotopes of lead in certain minerals and extractions.

Minerals	Object from which lead was isolated	Number of samples	$\frac{RaD}{Pb}$	$\frac{ThB}{Pb}$	$\frac{RaD}{ThB}$
1	2	3	4	5	6
Uraninite	Mineral	3	3.18±0.30	–	–
	20 days water extraction	2	6.12±0.82	–	–
	Repeated extraction in 0.5N HCl, 3 days	2	3.66±0.38	–	–
	Mineral after leaching	4	3.10±0.29	–	–
Same, control sample	Extraction 1N HCl, 10 days	4	3.71±0.39	–	–
	Mineral after leaching	2	3.15±0.35	–	–
Pitchblende	Mineral	4	10.13±0.93	–	–
	Extraction 0.5N HCl, 4 days	1	0.012±0.011	–	–
	Mineral after leaching	2	13.02±1.22	–	–
Same, control sample	Extraction 1N HCl, 14 days	2	0.62±0.10	–	–
	Mineral after leaching	2	13.41±1.25	–	–
Rock enriched by uranium black (in 1/5)	Rock	2	7.95±0.76	–	–
	Extraction 0.005N Na_2CO_3, 5 days	2	3.94±0.51	–	–
	Rock after leaching	2	7.80±0.79	–	–
Same, control sample	Rock	3	7.53±0.67	–	–
	Extraction 0.5N HCl, 23 days	1	4.96±0.60	–	–
	Rock after leaching	3	7.90±0.64	–	–
Same, control sample	Rock	9	7.74±0.40	–	–
	Extraction 0.07N $NH_4CH_3CO_2$, 8 days	4	4.58±0.43	–	–
	Sample after leaching	6	8.43±0.91	–	–
Rock, enriched by uranium black (in 2/5)	Rock	2	6.96±1.02	0.02±0.005	0.003±0.001
	Extraction 0.5N HCl, 56 days	1	4.41±0.58	0.11±0.02	0.025±0.003
	Sample after leaching	4	9.65±0.84	0.01	
Rock from the zone of fracture, enriched by uranium black (in 6/5)	Rock	2	6.36±0.56	–	–
	Extraction 0.5N HCl, 38 days	4	5.25±0.47	–	–
	Repeated extraction 0.5N HCl, 21 days	1	4.86±0.54	–	–
Brannerite	Extraction 0.5N HCl, 2 days	1	>0.3	>0.5	1.9
	Sample after extraction	1	>3.6	>0.5	0.14
Ferrithorite	Mineral	3	2.63±0.34	40.0±4.8	15.2±1.6
	Extraction 0.05N HCl, 8 days	1	>0.082	>1.8	22.0
	Mineral after leaching	2	2.36±0.34	39.4±5.4	16.7±1.8
Parallel sample	Extraction 0.005N Na_2CO_3, 3 days	1	0.064±0.017	1.9±0.5	29.7±4.6
Monazite	Extraction 1N HNO_3, 113 days	1	>0.08	>4.2	52.5
	Mineral after extraction	1	>0.1	>0.9	9.1
Parallel sample	Mineral after extraction	2	0.18±0.02	1.6±0.2	8.66±0.83
Wolframite	Mineral	2	0.35±0.05	–	–
	Extraction 0.5N HCl, 97 days	1	0.27±0.05	–	–
	Sample after extraction	1	0.28±0.04	–	–

Table 4 (continued)

The results of measurements of radioactive isotopes of lead in certain minerals and extractions.

Minerals	Object from which lead was isolated	Number of samples	$\frac{RaD}{Pb}$	$\frac{ThB}{Pb}$	$\frac{RaD}{ThB}$
1	2	3	4	5	6
ock, enriched by secondary uranium mineral	Rock	3	1.91±0.15	–	–
	Extraction 0.5N HCl, 59 days	2	1.76±0.23	–	–
	Sample after leaching	3	2.04±0.20	–	–
ontrol sample	Rock	6	1.92±0.14	–	–
	Extraction 0.07N $NH_4CH_3CO_2$, 9 days	2	1.85±0.10	–	–
	Rock after leaching	3	2.20±0.21	–	–
ecomposed mineral	Mineral	3	0.081±0.099	0.38±0.04	4.8±0.5
	Extraction 0.5N HCl, 24 days	4	0.093±0.099	5.15±0.49	55.8±5.6
	Mineral after leaching	3	0.073±0.008	0.40±0.04	5.55±0.60
ock, containing galena	Rock	1	0.070±0.007	<0.001	<0.01
	Extraction 1N HCl, 43 days	1	0.062±0.009	~0.005	~0.08
	Rock after extraction	2	0.066±0.007	<0.001	<0.01

ne extract by the radioactive isotope RaD as been observed.

PITCHBLENDE. Specific activity is equal o 10.13±0.93, which corresponds (with corection for actinium lead) to an age of 720 illion years; this is somewhat higher than ne geologic evaluation, possibly due to resence of nonradiogenic lead ore.

Specific activity of lead from hydrochloric cid extractions partly diminishes to 0.012 nd 0.62 which can be related to greater solation of ore lead. The mineral after eaching demonstrates a considerable inrease in specific activity (up to 13.02 and, or the control sample up to 13.41), because ne coefficient of leaching in this case is arge (3.3-8.9 percent).

The rocks enriched by uranium black. Lead isolated from water, soda and hydrohloric acid extractions, demonstrates, as vell as pitchblende, the diminution of speific activity in comparison with lead from he minerals. However, this diminution is ot very great. Actual age of such formaions according to RaD/Pb^{206} is from 0.6 to .1 billion years and is undoubtedly higher han the geologic evaluation, i.e., these ninerals contain primarily lead ore.

In this case it is possible with some ertainty to assume the separation of ore ead in solution. Specific activity of lead n minerals after leaching increases considerably. Here, similar to the case of pitchblende, the losses of lead of lesser specific activity provoke a noticeable increase in specific activity of the mineral.

In one case (sample 2/5), we managed to determine the sharp enrichment in the lead extracted by thorium B. ThB/RaD ratio = 0.025, and for the mineral after leaching -- ThB/RaD $< 2 \cdot 10^{-3}$; i.e., in this case the preferable extraction ThB is sharply demonstrated.

BRANNERITE. It has been possible to determine only the ratio of isotopes ThB and RaD. For the mineral ThB/RaD is equal to 0.09 (in relation to the matrix matter), and for the extraction it is increased up to 1.8, i.e., 20 times. In the mineral, left after extraction, the ThB/RaD ratio = 0.14 (within the limits of analytical error) corresponds to an initial value found from the ratio of thorium and uranium. In this case, the prevailing fractionation of ThB in comparison with RaD has also been observed.

FERRITHORITE from polymetallic ore bodies demonstrates a small specific activity (2.63±0.34). If the great content of the thorium lead is taken into consideration, then actual age of the rock, from RaD/Pb^{206} ratio, should be something around 500 million years. This value probably is slightly higher than the geologic evaluation of the age, which is quite natural, because a mineral from polymetallic ore body can be enriched

by the ore lead. In this case the content of ore and radiogenetic lead is probably close to the value, and for the evaluation of their relative content, a mass-spectrometric measurement is necessary. The lead from a weakly-leached extraction demonstrates the strong (more than 40 times) diminution of the value RaD/Pb; i.e., predominantly nonactive lead extraction is taking place. The mineral after leaching possesses practically the same specific activity as the initial mineral. ThB/RaD ratio in extraction increases approximately twofold. However, the specific activity ThB extraction (ThB/Pb = 1.9) is considerably smaller than in mineral (ThB/Pb=40). Therefore, ThB is isolated in solution to a lesser degree than inactive ore lead, but to a slightly higher degree than RaD.

MONAZITE. Thorium-uranium ratio of mineral is 9.3. In nitric acid extraction from a mineral, the ratio ThB/RaD = 53.0, but in the mineral after leaching it is 8.7 to 9.1. Predominantly ThB isolation (in comparison with RaD) occurs.

WOLFRAMITE. This mineral possesses a low specific activity (RaD/Pb=0.35). Undoubtedly most of the lead is nonradiogenic. Specific activity of lead from extraction (within the limits of analytical error) do not change.

Rock enriched by secondary uranium mineral demonstrates a low specific activity (1.9), i.e., considerably greater ore lead content (actual age around 3 billion years). RaD/Pb ratio in extraction by ammonium acetate remains practically the same, and in hydrochloric acid it diminishes slightly corresponding to the ratio for the mineral.

Decomposed mineral of the oxide type has very low specific activity (predominance of ore lead) RaD/Pb ratio for the lead from hydrochloric acid extraction is also practically unchanging. However, the ThB/RaB ratio increases approximately tenfold in comparison with the same ratio for the mineral. In Figure 2, the change of activity of preparates from this sample is shown.

Rock, enriched by galena and radioactive minerals. Low RaD/Pb ratio supports the prevalence of ore lead. For lead from hydrochloric acid extraction this ratio practically does not change, and the ThB/RaD ratio increases up to 0.08, i.e., almost in an order of value in comparison with the mineral (where it cannot be measured and ThB/RaD <0.01).

Conclusions

1. Nonradiogenic ore lead may be isolated

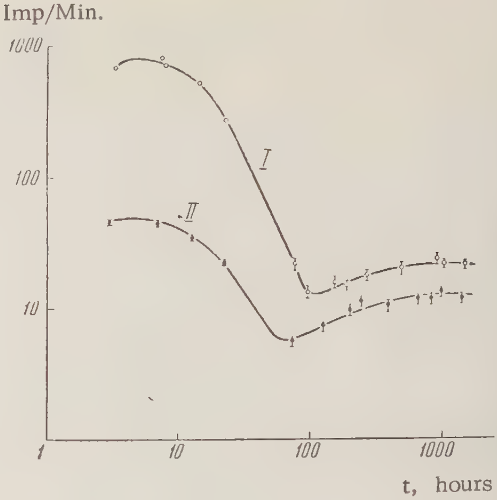

Fig. 2. Decomposed mineral of the oxide type.

I - Change of beta-radiation intensity for the lead preparates from extraction;

II - The same from mineral after leaching.

from primary minerals in greater quantities than radiogenic and radioactive isotopes of lead.

2. RaD is extracted from uraninite to a greater degree than radiogenic stable isotopes of lead.

3. ThB is leached to a greater degree than RaD.

4. The following series of isotopes is arranged in decreasing order of ability to change into the liquid phase from primary minerals: ore lead and ThB > RaD > radiogenic Pb.

This sequence coincides with the general law of fractionation of radioactive isotopes (greater amount in leaching for short-living isotopes and preferable leaching of subordinate elements) and agrees with Tilton's data on preferential fractionation of ore lead in comparison with radiogenic.

5. In the majority of minerals, lead is found in subordinate quantities in comparison with the radioactive elements. Prevalence of lead has been observed only in secondary and changed minerals, in wolframite and particularly in two secondary minerals (decomposed oxides and rock enriched by galena). In these cases, no difference of RaD/Pb ratio in the lead from extractions and the lead from minerals has been observed.

For the rock enriched by secondary minerals of uranium with relatively high lead content (U : Pb = 2), an insignificant change of specific activity in extract (as far as the limit of experimental error permits) occurs.

We can consider the regularities described above as only preliminary. The data need completion and refinement. We consider especially important the further investigation of uraninite. According to our data leaching of lead from uraninite is accompanied by considerable change in its isotope content. Evidently, while investigating the behavior of lead inside certain geochemical complexes, we have to account not only for the possibility of lead of different isotope content entering, and not only the change of this content in radioactive minerals, but also the fractionation of isotopes of lead during its migration.

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DIFFERENTIATION OF SILICATE MELTS UNDER INDUSTRIAL CONDITIONS AND THEIR GEOLOGIC SIGNIFICANCE

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ABSTRACT

The article deals with the results of large-scale industrial experiments on differentiation of silicate melts of general petrographic interest: 1) The enrichment of the upper levels of the melts in iron with crystallization of iron-rich olivine and development of pegmatoid textures; contemporaneous differentiation in lower sections of magnesian olivine; 2) precipitation of unmelted olivine from the furnace charge into lower levels of the slag with enrichment in magnesium oxide and sharp increase in viscosity of silicate melts containing the solid phase.

* * * * *

One of us recently [4] has described certain cases of differentiation of silicate melts including that of nickel slag. Supplementary material on original differentiation of liquid refuse from water jacket and electric furnace slag, as distinct from melting of sulfide rocks, has appeared recently.

The interest in studying such cases of differentiation of silicate melts is increasing because similar processes are observed in natural magma. These studies are of special interest during the study of volcanic activity and extrusion of basalt lava. Examples of lava differentiation are given in the papers of S.I. Naboko [5], B.I. Piyp [7], and V.I. Vlodavets [2]. It is shown in these papers that lava extruded from the upper central crater usually has greater acid content than the lava of lower craters. The changes in chemical content of lava are parallel with the change of its mineralogic content. B.I. Piyp [7] shows, in one study, that the pyroxene of a lower crater contains less calcium and more magnesium than the pyroxene of the related upper crater. S.I. Naboko has also noted the increase in refractive indices of pyroxenes from lava from the lower to the upper craters, and has explained this increase by an increase of iron content of the pyroxene. On the other hand, B.I. Piyp stated that at the beginning of eruption, more acid lava flowed from the channel; at the end of eruption the lava was more basic. The pyroxene content has always been the same. Olivine was, in the beginning of eruption, richer in iron, and at the end of eruption it became more magnesian. V.I. Vlodavets [2] shows, in another study, that the olivine in lava flowing from the lower parts of the volcano contains 10 to 12 percent of the fayalite component. With increase in height to the top of the crater, the quantity of fayalite in the olivine grows up to 27 percent. In monoclinic pyroxene of the diopside-hedenbergite series, the hedenbergite content was increased from zero in the sample from the 600-meter level to 36 percent in the sample from the top of the volcano.

To study experimentally and to verify the direction of differentiation in silicate melts seems to us impossible, using small laboratory crucibles. The experiments on crystallization of melts in large volume are very rare. We have had an opportunity to conduct and observe in industrial conditions such experiments of crystallization of silicate slag melts on a large scale in one metallurgical factory; we think that the material below is of interest for all petrographers.

The experiment was conducted in the following manner: Liquid slag, flowing from a water jacket furnace, was poured into a dipper 2.2 meters high and 1.75 meters in diameter. Slag melts were cooled slowly for five days, and after the dipper was overturned, slag was extracted and broken into pieces by means of an electromagnetic drop hammer. The sample was taken from the center and the periphery of the upper, middle, and lower parts of the slag block

(see Fig. 1).

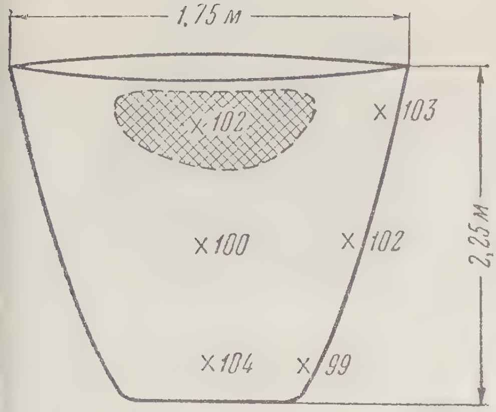

Fig. 1. The method of sampling the slag, which crystallized in the dipper.

The region of coarse crystallization is cross-hatched.

Macroscopically the slag was dark grey. Its texture was heterogeneous: more intensive cooling of slag had taken place at the bottom and at the sides of the dipper; therefore, the slag at these places was denser. The degree of crystallization of slag slightly decreased from the edges to the center. At the top, in the central part of the dipper, a void of great volume had formed. This void was surrounded by slag of coarse crystalline texture (see Figs. 2 and 3) very different from the general fine-grained mass of the block (see Figs. 4 and 5).

Mineralogic content of the slag block was originally uniform and was represented by olivine, hedenbergite, sulfide, magnetite, and glass. However, the final proportion of olivine and magnetite in different sections of the block varies considerably (see Table 1).

Olivine possessed an idiomorphism in section; it is colorless in the lower parts of the block and is a weak yellow-brown in the upper part. Cleavage (001) is distinct to less distinct (010). The plane of the optic axis is parallel to (001). Optical orientation of (010) is Ng = 90°; (010), Np = 90°; (010), Nm = 0. The optic angle for olivine from the lower part of the slag (Sample 104) is equal -- 80°, and for olivine of the upper part (Sample 102) -- 68°.

Hedenbergite was present in the form of xenomorphic grains between the crystals of olivine; it possessed distinct pleochroism in yellowish-green shades. Optic orientation (110), Ng = 59°; (110), Nm = 43°; (110), Np = 69°. Plane of optic axis parallel (010);

Table 1

Quantitative Mineralogic Content of the Slag Block.

Minerals	Sample 102, upper part of slag		Sample 104, lower part of slag	
	Volume %	Weight %	Volume %	Weight %
Olivine	69.0	69.5	61.1	61.9
Hedenbergite	17.1	15.5	18.7	17.1
Sulfides	3.7	4.5	3.1	4.1
Magnetite	7.2	8.8	10.2	13.5
Glass	3.0	1.7	6.9	3.4
Total	100.0	100.0	100.0	100.0

2V = (+) 68-70°, cNg = 47-48°.

Magnetite was present in the form of inclusions in olivine and sulfides, therefore its differentiation takes place during the entire period of crystallization of slag.

Sulfides were represented chiefly by pyrrhotite and bornite. In the grains of pyrrhotite oriented inclusions of pentlandite are visible. Pentlandite is a product of unmixing from solid solution.

In the lower as well as in the upper parts of the slag block some (1.7 to 3.4 percent by weight) silicate glass was found.

The crystal grains of magnetite and sulfides at the top of the block were considerably greater than at the bottom. The great quantity of magnetite and its greater crystallization at the top than at the bottom of the block are illustrated in Figures 6 and 7.

It has been determined by immersion studies of olivine that its composition was not the same in the lower and the upper part of the block. This encouraged us to start a more detailed study of heterogeneity of the slag. The constants of light reflection for olivine and hedenbergite from the upper, middle, and lower part of the slag are given in Table 2.

The directions of strong vibrations of refracted light for olivine and hedenbergite remain practically the same in the vertical section of the block but around the block.

From the data of Table 2 and the Diagram of the relationship of refractive indices to the olivine content in the series Mg_2SiO_4 [1], Table 3 shows the olivine content across a section of the slag block.

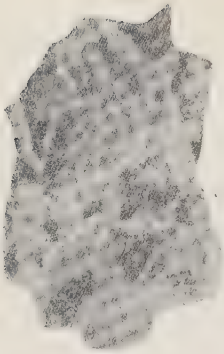

Fig. 2. Coarse crystallization of olivine from top of the dipper, Sample 102.

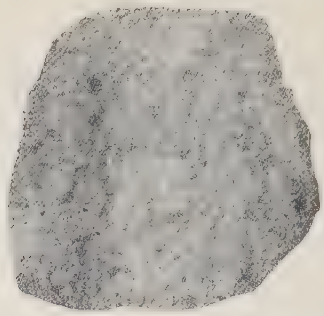

Fig. 4. Fine-grained mass of slag from bottom of the dipper, Sample 104.

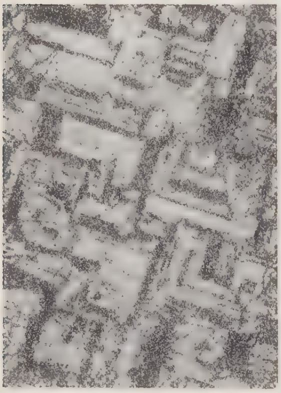

Fig. 3. Pegmatoid texture of the slag, sample 102.

Magnified 45X, without analyzer.

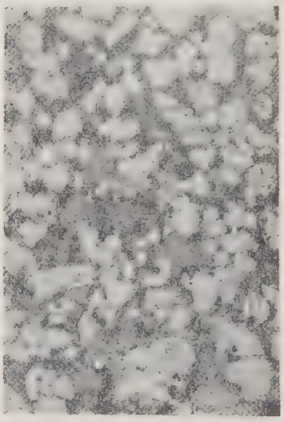

Fig. 5. Fine-grained texture of the slag from bottom of the dipper, Sample 104.

Magnified 90X, without analyzer.

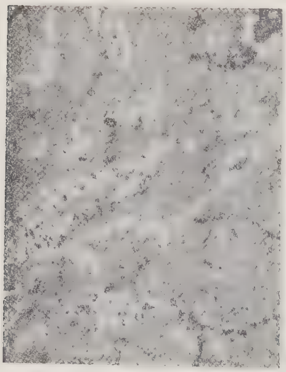

Fig. 6. Large grains of magnetite in the slag from top of the dipper, Sample 102.

Magnified 85X, reflected light.

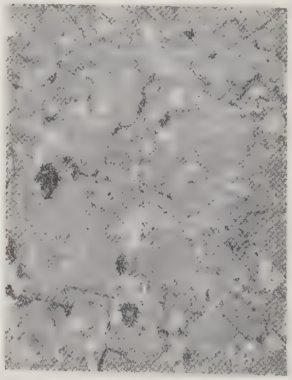

Fig. 7. Small grains of magnetite in the slag from bottom of the dipper, Sample 104.

Magnified 85X, reflected light.

Table 2

Refractive indices for olivine and hedenbergite in different sections of the slag block.

Horizontal part of the block	Olivine		Hedenbergite	
	Ng	Np	Ng	Np
	Central part of the block			
Top (Sample 102)	1.786	1.754	1.756±0.004	1.734±0.002
	to 1.833	to 1.793		
Middle (Sample 100)	from 1.785	from 1.757	1.750±0.004	1.728±0.002
	to 1.830	to 1.790		
Bottom (Sample 104)	from 1.784	from 1.747	1.753±0.004	1.730±0.004
	Lateral part of the block			
Top (Sample 103)	from 1.780	from 1.749	1.750±0.003	1.734±0.003
	to 1.844	to 1.806		
Middle (Sample 101)	from 1.784	from 1.754	1.752±0.002	1.726±0.003
	to 1.833	to 1.780		
Bottom (Sample 99)	from 1.773	from 1.750	5.752±0.005	1.731±0.004
	to 1.810	to 1.782		

Table 3

Fluctuation in olivine content in different parts of the slag block.

Horizontal parts of block	Central part				Lateral part			
	No. of Sample	Ng Average	FeO Wgt. percent in olivine	Fe_2SiO_4 Mol. percent in olivine	No. of Sample	Ng Average	FeO Wgt. percent in olivine	Fe_2SiO_4 Mol. percent in olivine
Top	102	1.810	52	68	103	1.812	53	69
Middle	100	1.807	51	65	101	1.809	52	68
Bottom	104	1.796	48	60	99	1.791	47	57

To determine in more detail the variations in chemical composition developed as a result of heterogeneity in the slag block, two analyses of Sample 102 (top of central part) and Sample 104 (bottom of central part) were executed. The results of analyses (assayer O.P. Ostrogorskaya) are given in Table 4.

As is evident from the tables, the top of the block contains more silica, coinciding with higher olivine content. Higher ferrous oxide content and greatly lowered percent of magnesium oxide corresponds to the higher fayalite content in olivine in the top part of the block as compared to the lower part.

The iron oxide content from chemical analysis was compared with the quantity calculated from the number of phases counted under the microscope. The data are given in Table 5. The results obtained from both methods are very close. The slightly

Table 4

Chemical content of the top and the bottom parts of the slag block (in percentage).

Oxides	Top of slag Sample 102	Bottom of slag Sample 104
SiO_2	32,56	30,25
TiO_2	0,26	0,23
Al_2O_3	4,48	4,14
Fe_2O_3	4.44	5,60
FeO	44,01	42,52
MnO	0,09	0,08
MgO	2,42	9,52
CaO	8,52	5,08
Na_2O	1,23	0,63
K_2O	0,70	0,38
CuO	0,20	0,52
NiO	0,07	0,72
CoO	0,13	0,15
S	1,29	1,29
Total	100,40	101,11
$-O_2=S$	0,64	0,64
	99,76	100,47

Note: Comma represents decimal point.

greater discrepancy in Sample 102 is very likely explained by the sharp fluctuations in olivine content and by a certain heterogeneity of the coarse crystalline slag.

While explaining the reason for the described heterogeneity in the upper and the lower parts of the slag, we have to indicate that it cannot result from initial neterogeneity of the liquid slag. Observations showed that the chemical composition of the slag flowing from the furnace is uniform.

The possibility of enrichment of the lower levels of slag melts in magnesium because of melting of refractory materials by the slag was precluded because the magnesite living in the dipper was not present.

Heterogeneity originates during the process of crystallization in melts of large volume. Crystallization starts with differentiation of higher temperature and magnesium-rich olivine. The residual melt, enriched by iron and gas phases, is displaced to higher levels of the slag dipper. Due to formation of a hard, refractory crust on the surface of the slag, the gases cannot escape from the melt and accumulate at the top, forming a large quantity of gas, the appearance of which is also caused by shrinking phenomena in hardening slags. A favorable condition exists for crystallization of large concentrations of ferrous olivine and magnetite in the region where the slag has been in liquid condition a longer time, if contact with this gas occurs.

During enrichment of residual melts by iron there is no leveling in the iron content of olivine crystals. It is characteristic that crystals of olivine with greater ferrous content grow not because of formation of zonal

Table 5

Ferrous oxide content in the lower and bottom part of the block according to calculation and from chemical analyses.

Minerals	FeO content in weight percent	
	Top of slag Sample 102	Bottom of slag Sample 104
Olivine	36.14	29.7
Magnetite	2.73	4.19
Hedenbergite	4.56	5.03
Sulfides	3.50 (Converted to FeO)	3.19 (Converted to FeO)
Total	46.93	42.11
According to chemical analysis	44.01	42.52

crystals but by development of new centers of crystallization of olivine enriched in fayalite.

Such a process of differentiation has been described for crystallization of sulfide-silicate melts by Ya. I. Ol'shanskiy [6]. In his experiments, the crystallization of melts resulted in squeezing out to the upper sections in the crucible the later segregations of sulfides; these late sulfides formed sulfide beads on the top of crystallized melts. Therefore, the heavier but fusible phases are distributed above the lighter but slow-melting minerals here as in the dipper slag, as the result of crystallization.

There is no doubt that similar differentiation phenomena are quite possible during the crystallization of basic and ultrabasic magma rich in magnesium and natural iron.

Let us study one more case on heterogeneity of slag melts in the nickel slags of the same factory. At the border of the liquid sulfide and silicate layers very viscous slag forms in electric furnaces and in settling units of the water jacket furnace. This interlayer causes many difficulties in production, preventing settling of the sulfides in slag and increasing the loss of valuable metals (nickel, cobalt, copper). Therefore, determination of the reasons for heterogeneity in slag melts is of considerable practical interest.

Microscopic study of the section showed that the heterogeneity is the same in the slag from the water jacket settler and the electric furnace. We will limit ourselves, therefore, to a detailed description of this phenomenon in the electric furnace.

The distribution of the normal slag, its viscous layer, and matte in an electric furnace and in the settler of the water jacket furnace is represented in Fig. 8. The total thickness of the slag is about one meter, the thickness of the viscous layer is 0.28 meters and the thickness of the matte is 1.7 meters. The samples of normal slag can be taken by the laddle and the samples of the viscous layer only by "freezing" the melt on the bar lowered into the layer of slag in the electric furnace or settler. The bar was kept 8 to 10 minutes in the settler and 6 to 8 minutes in the electric furnace. A layer of viscous slag 6 to 8 mm thick adhered to the bar in the electric furnace, and 10 to 25 mm thick in the water jacket settler.[1]

[1] The samples were taken by the engineer of the factory, N.I. Gran', to whom the authors are grateful.

The study of thin and polished sections from the samples of slag has shown that in both cases the character of heterogeneity is almost the same and that the viscous layer of slag, in contrast with the normal slag at the top, is similar in composition to unmelted rock.

Normal water jacket and electric furnace slags from the melting of nickel sulfide ores, as detailed investigation of one of them showed [4], are from magnesium-iron olivine, hedenbergite, magnetite, sulfides (pyrrhotite, bornite, pentlandite) and glass.

In the slag studied by us (Samples 35-58 and 35-61), due to their quick cooling only olivine can be recognized in thin section; between the grains of olivine is the dark isotropic mass of glass and sulfides. Small sulfide grains are clearly visible in polished sections. The microtexture of electric furnace slag, Samples 35-58, is represented in Fig. 9.

The viscous layer of slag differs from normal slag by the presence of melted relicts of olivine of waste rock as in Fig. 10. The size of relict grains reaches 2 mm. Samples 35 to 59 of the slag from the settler of the water jacket furnace differ from Samples 35 to 58 by less perfect skeletal crystallization of olivine. Together with the few large phenocrysts of olivine there are partly resorbed accumulations of small grains of olivine; both varieties formed evidently on account of crystallization of olivine of the furnace charge.

In the viscous layer of the slag, Samples 35 to 59, from the settler, together with inclusions of the furnace charge olivine whose grains range up to 2 mm, there were fragments of glassy rocks with relicts of melted grains of quartz, plagioclase, and pyroxene. We have studied in detail more of the formations of the viscous stagnant layer of slag on the border of matte in the electric furnace. Chemical analyses of this layer (Samples 35-59) and the normal slag (Samples 35 to 58) are given in Table 6 (Assayer P.P. Ostrogorskaya).

Chemical analysis indicates the uniformity in the content of all elements except magnesium in the slag and in its viscous layer. Magnesium oxide in the viscous layer is 5.38 percent more than the normal above late slag. To explain the reason for such a difference, microscopic counting of phases and determination of optic constants of olivine has been carried out; olivine is the main magnesium-bearing phase of the slag studied.

The results of calculations of the phase

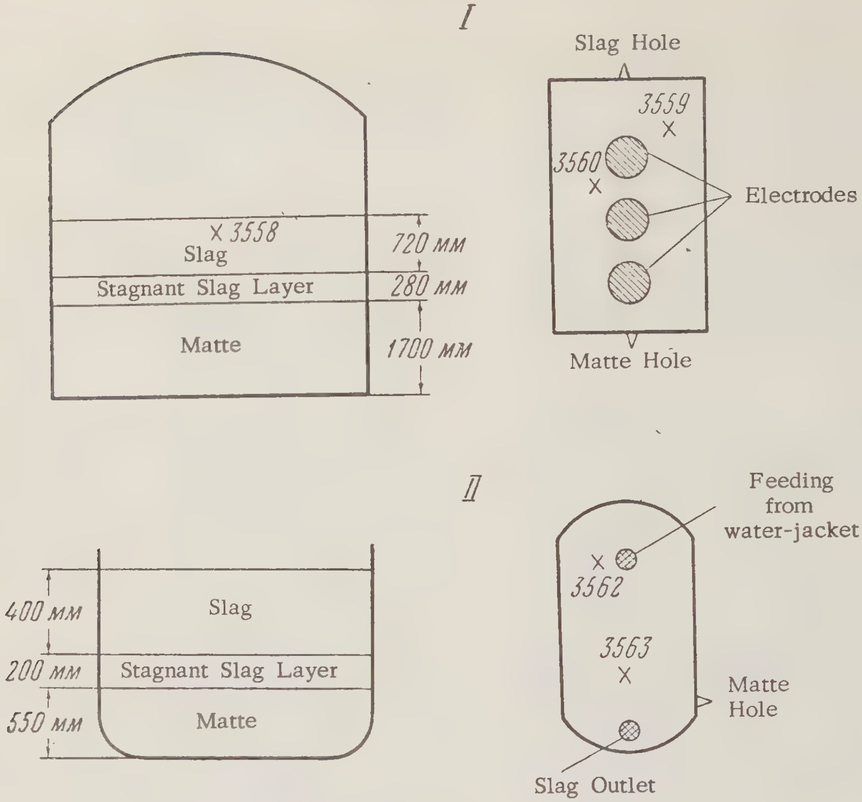

Fig. 8. Methods of taking slag samples.

I - From an electric water furnace
II - From a water-jacket furnace

composition of the slag are given in Table 10.

As indicated in Table 7, the sharpest difference of the viscous layer from the upper normal layer is the presence of 21 percent of olivine in the viscous layer; this olivine is from the waste rock, not having been assimilated by the melting and thus, only partly melted.

Further microscopic investigation of olivine has determined the optic constant (see Table 8).

Therefore, the refractive indices of olivine crystallized from the slag are close in Samples 35-58 and 35-59 and considerably higher than the refractive indices of the section olivine.

In olivine crystallized from the slag melt, there are 24 mol. percent of fayalite and in relict olivine -- 10 mol. percent Fe_2SiO_4, based on the diagram of the relationship between refractive indices of olivine and its position in the series Mg_2SiO_4 - Fe_2SiO_4. According to N. N. Kurtseva [4], refractive indices of olivine from the rock containing sulfide ores are: $Ng = 1.698$-1.704; $Np = 1.662$-1.668, which almost coincides exactly with indices of relict olivine from Samples 35-59, and therefore confirms that this olivine is from the unmelted residue of this rock.

Fe_2SiO_4 content in this olivine is 10-14 mol. percent; the remaining 90-86 percent is usually Mg_2SiO_4. About the same content of Fe_2SiO_4 (8-13 percent) in olivine from pyroxenite in Monche-tundra has been determined on the basis of optic constants by B.M. Kupletskiy [3]. Their melting point is at 1,700 to 1,990° C. and the melting is fully completed at 1,850 to 1,870°C.

Temperature in furnaces for melting nickel ore is usually not over 1,400°. Because of that, the larger grains of olivine of the base rock reacted only partly on the surface with surrounding materials and remain unabsorbed by the slag melt and were gradually precipi-

ted and accumulated in the lower level of ie slag.

Table 6

Chemical composition of normal slag (Samples 35-58) and the viscous lower layer (Samples 35-59) from the electric furnace.[1]

Oxides	Samples 35-58	Samples 35-59
SiO_2	42,83	41,60
TiO_2	0,50	0,36
Al_2O_3	4,06	3,05
Fe_2O_3	1,61	0,91
FeO	24,64	23,55
MnO	0,13	0,13
MgO	21,16	26,54
CaO	2,30	1,61
Na_2O	1,55	1,01
K_2O	0,33	0,27
P_2O_5	0,10	0,09
Cr_2O_3	0,37	0,30
S	0,57	0,58
Ni	0,01	0,10
Co	0,04	0,04
Cu	0,02	0,11
Total	100,22	100,25
$-O_2=S$	0,28	0,29
	99,94	99,96

[1]FeO is only approximate because the sample tained sulfur.

e: Comma represents decimal point.

The presence in liquid slag of about 1/3 f the solid phase considerably decreases its uidity and can cause the mashed condition f the slag which impedes precipitation of ulfide from the slag to the matte.

As indicated in Table 7, there is less ulfide in the lower viscous layer than in ie upper levels of the slag. This is caused, vidently, by the fact that the penetration of ulfides into the thick, lower layer of the lag is hampered by the formation of a iickened slag layer on the border; the suldes accumulate on the surface of the iickened slag layer.

Conclusions

Two cases of differentiation in nickel slags have been described.

In both cases, it was determined that the upper layers are noticeably enriched in iron oxide and become impoverished in magnesium oxide in comparison with the lower layer of the slag. However, the causes of this heterogeneity of the slag melts are completely different.

In case of crystallization of water jacket or of electric furnace slag (SiO_2 = 30.2-32.6; FeO = 42.5-44.0; MgO = 2.4-9.5; CaO = 5.0-8.5 percent) in large dippers about 25 tons capacity during the crystallization of the melt, the first iron-magnesium olivine of approximately 60 mol. percent Fe_2SiO_4-40 percent Mg_2SiO_4 starts to settle. The residual melt, enriched in iron and deficient in magnesium is concentrated in the upper part of the dipper, where gases accumulate under the insulating crust and form a great gas region. In these regions the olivine of greater iron content (up to 68 mol. percent Fe_2SiO_4) is differentiated, and in the zone adjacent to the gas void it is very coarsely crystallized; the slag in this area acquires a pegmatoid texture. The magnetite from here also consists of considerably larger grains than at the bottom of the slag block.

Therefore, differentiation occurring during crystallization of melts enriches the upper levels in heavy and easy melting minerals, expelling them in the last stage of the process. An analogy with the experiment of Ya. I. Ol'shanskiy can be seen; there sulfide dissolved in the silica melt and crystallized with it in the form of small beads on the surface of the crystallized melt in the crucible. The process of differentiation similar to that described undoubtedly can occur under natural conditions in ultrabasic magma enriched in magnesium and iron. Examples have been given in this article.

The second case in the differentiation of slag in the nickel industry takes place in the settler of the water jacket furnace and electric furnace (composition of slag, SiO_2 = 41.6; FeO = 23.6-24.6; MgO = 21.2-26.5 percent) and permits us to explain the reason for the formation of the very viscous layer below the slag at its border with the matte.

The high viscosity of this layer is believed to be due to the accumulation of

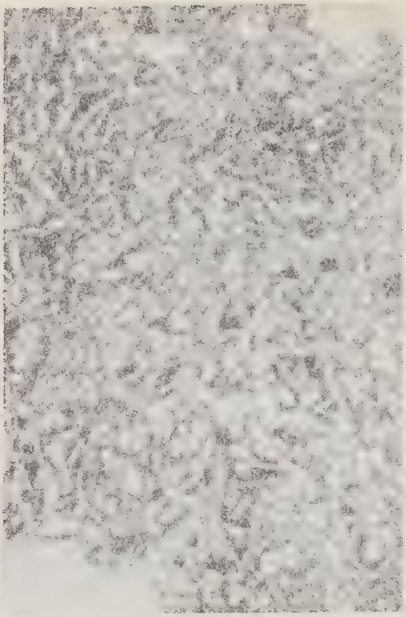

Fig. 9. Microtexture of electric furnace slag, Samples 35-58. Magnified 20X without analyzer.

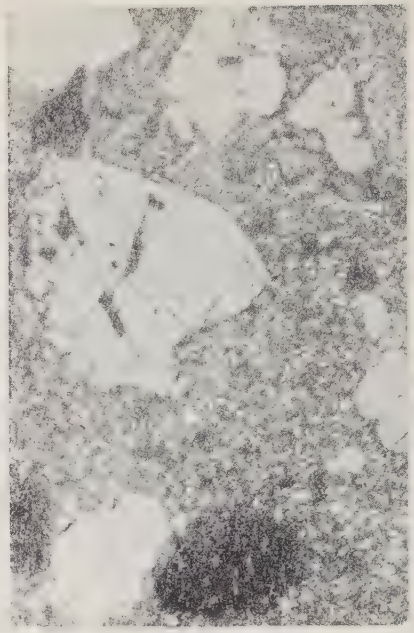

Fig. 10. Melted relicts of olivine, Samples 35-59. Magnified 20X without analyzer.

Table 7

Quantitative phase content of normal slag (Samples 35 to 58) and its lower viscous layer (Samples 35 to 59)

Mineral	Samples 35-58		Samples 35-59	
	Vol. %	Wgt. %	Vol. %	Wgt. %
Olivine on account of waste rock	—	—	24,6	24,00
Olivine, coarse " fine in glass	$\left.\begin{matrix}55{,}4\\19{,}1\end{matrix}\right\}69{,}5$	$\left.\begin{matrix}52{,}3\\21{,}6\end{matrix}\right\}73{,}9$	$\left.\begin{matrix}46{,}4\\12{,}0\end{matrix}\right\}58{,}4$	$\left.\begin{matrix}47{,}8\\12{,}4\end{matrix}\right\}60{,}2$
Total olivine	69,5	73,9	83,0	84,2
Sulfide	3,7	5,2	2,8	3,6
Magnetite	0,5	0,8	—	—
Glass	21,3	20,1	14,2	12,2
Total	100,0	100,0	100,0	100,0

Table 8

Olivine	Samples 35-58			Samples 35-59		
	Ng	Np	(—)2V	Ng	Np	(—)2V
Main mass	1,705—1,710	1,662—1,672	87°	1,720	1,680	87°
Furnace charge	—	—	—	1,683—1,700	1,658—1,661	84°

Note: In Tables 7 and 8, comma represents decimal point.

coarse grains from not fully-melted olivine of the waste rock. The refractive indices of these grains (Ng = 1.683-1.700; Np = 1.658-1.661) corresponds exactly to those of the olivine of rocks which contain sulfide ores and is never less than slag olivine (Ng = 1.720; Np = 1.680).

The quantity of hard grains of olivine in the slag melt, commonly as much as 30 percent, greatly increase the viscosity of the liquid slag and at some point cause development of the mashed-like texture.

This consistency of the slag considerably hampers the precipitation of sulfides from slag into matte and increases the loss of nickel in the slags.

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ALTERATION OF CRYSTALLINE SCHIST DURING HEATING

by

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ABSTRACT

Crystalline schist, incorporated in the refractory lining of a lime kiln, was recrystallized from the liquid state after insignificant, partial development of a glass phase, during development of a glass phase, during operation of the kiln. The initial minerals of the rock, actinolite and albite, were changed to pyroxene, melilite, and plagioclase, and thin microlayers were formed which resemble a microskarn.

* * * * *

INTRODUCTION

During the formation of metamorphic rocks, and particularly of crystalline schist, the processes of recrystallization in the solid state play a major role.

F. Yu. Levinson-Lessing [6] in studying crystalline schist, considered it important to include knowledge from industrial processes in experimental petrography. He wrote: "It seems to me that there is a possibility of utilizing the material which I like to call semi-experimental for the study of the transformation of minerals present in relatively great quantity in metallurgical furnaces. This idea is the result of the observation of the change of dinas bricks by Professor V. Ye. Grum-Grzhimaylo. Recently Professor V. Ye. Grum-Grzhimaylo drew my attention to changes in other material in the furnace, for example, magnesite. There is no doubt that in this case we are dealing with the phenomenon of recrystallization of the heated mineral masses from the liquid state -- in some cases with partial melting -- and that here we can find many factors which can explain a certain part of the history of crystalline schist" ([6], p. 354).

Later, F. Yu. Levinson-Lessing himself took part in the study of recrystallization of rock in the solid state [7]. For this purpose he put a sample of Ural dunite in a Martin oven, where it was subjected to the prolonged effect of the oven temperature of 1,200 to 1,400° for 9 months. The sample of the rock removed from the furnace was not disintegrated and its initial form was fully retained. The careful study of thin sections of the dunite, after its stay in the Martin furnace, showed that the original olivine of the rock was noticeably changed. The grain structure acquired undulating outlines which caused closer contact between grains; brown iron oxides resulted from the degeneration of the fayalite component of olivine. Instead of serpentine, olivine was formed together with rhombic pyroxene and clinoenstatite with typical polysynthetic twins. Therefore, this experimental investigation demonstrated the possibility of recrystallization of rock in the solid state. Favorable conditions for study of this problem are therefore available where the rock under study serves as a fire resistant lining of a high-temperature, industrial furnace. Some cases of utilization of this technique are known; some examples are described, but, unfortunately in these investigations, data on chemical and mineralogic changes of the rock are in question.

Therefore, due to the kindness of A. V. Sidorenko in providing us with a block of rock after its service in the lining of the furnace, we subjected this rock to thorough petrographic investigation. The block of rock, investigated by us had originally been taken from a dike of green schist correlated with limey shale layers of the Imandra-Varzuga formation; this, according to the data of geologists from the Kol'skiy Affiliate of the AN SSSR.

During its operational time in the lime furnace, the block of schist changed considerably as evidenced by formation of four distinct colored zones: a) dark green schist (original rock), b) grey, c) brown, and d) chocolate brown. On the surface subjected to the most heat, a partial melting of the rock occurred accompanied by development of small cavities filled with a light grey, fine-grained material.

Petrographic Description of the Crystalline Schist in Its Original State

The description of the sample (sample 433-a) in its original state prior to heating is given here in detail, because it is a unique standard with which other phases are compared.

Besides, this rock has not been previously described by petrographers. It is a dark green, dense rock with distinctly schistosity; the planes of schistosity are commonly covered by iron oxide (Sample 433-a). Thin green needles are present in fractures. The rock is altered (to a depth of 5 to 10 mm), and the surface layer is golden-brown. In its appearance and because of the fractures, the rock resembles an amphibolite. The length of the section of the block studied is about 70 mm.

According to A.B. Sidorenko, who visited the dikes, small crystals of pyrite and magnetite are present in the rock. In the sample studied, these minerals were not present.

In thin section, the rock consists of actinolite and the products of its transformation, albite, epidote, and an ore mineral. The main minerals of the rock -- actinolite and albite -- are stretched in one direction.

Elongated grains or felted aggregates of actinolite are not uniform in size and are as large as 0.12 by 0.85 mm in cross section. Most of the coarse grains of actinolite have sharp edges; some of them are bent, indicating that they were subjected to deformation (Fig. 1). In coarser crystals of actinolite, a dark, isotropic section representing the alteration product of actinolite is present. The color of the actinolite under transmitted light is light green. The actinolite is weakly pleochroic: Ng = light green, Np = bluish green. The optical constants, as determined from the washed section are: Ng = 1.652 $\pm$ 0.002; Np = 1.626 $\pm$ 0.001; Ng-Np = 0.026; cNg = 18-19°; (-) 2V = 73°. This data corresponds to actinolite with a noticeably high iron oxide content.

Products of the change of actinolite of olivine-green color are optically isotropic and their refractive index is closer to 1.630.

Fig. 1. Albite-Actinolite Schist, Sample 433-a. Magnified 76X, without analyzer.

The visible area consists of large spots of fine-fibered actinolite. Dark gray sections are products of actinolite alteration. The light sections are albite accumulations. The large grain in the lower left-hand corner is epidote. The black, idiomorphic segregations are magnetite (the ore mineral).

It is hard to speak about actinolitic nuclei of crystallization, because they form infinitesimally thin needles in felted aggregates which occupy a great part of the section. The maximum dimension of such aggregates in the section is 0.12 by 0.85 mm. Next in importance is albite, which usually crystallizes in the form of fine grains 0.15 by 0.15 mm in cross section. In places, small grains of albite form aggregates with an area up to 0.40 by 0.60 mm. The optical constants of albite are: Ng = 1.773 $\pm$ 0.002; Np = 1.732 $\pm$ 0.003; Ng-Np = 0.041; (-) 2V = 84°.

Among the accumulation of albite crystal aggregates, simple twins with prevailing dimensions of 0.04 by 0.10 mm are also present. Because very thin needles of actinolite are commonly present in the albite aggregates we can assume that albite has crystallized after actinolite. The very type of albite

crystallization testifies that it fills the interstices between the coarser crystals of actinolite.

Secondary minerals in the rock are epidote and the ore minerals. They are quite uniformly distributed but epidote sometimes forms an accumulation. Epidote is light green and grains range in size from very fine (<0.001 mm) to coarse -- 0.50 by 0.60 mm; the prevailing size is considerably smaller, about 0.01 by 0.01 mm. Optical constants of epidote are: $Ng = 1.773 \pm 0.002$; $Np = 1.732 \pm 0.003$; $Ng - Np = 0.041$; (-) $aV = 84^{\circ}$.

It is weakly pleochroic from light green to almost colorless.

This data indicates the epidote is rich in iron. The ore mineral is absolutely black; its uniform distribution in thin section in the form of small idiomorphic grains with cross sections up to 0.35 by 0.60 mm is apparent; the prevailing size, however, is 0.03 by 0.04 mm.

During examination of the polished section consisting predominantly of magnetite, isolated grains of pyrite were observed. A quantitative mineral analysis of the rock is as follows (in volume-percent):

Actinolite, fresh	58.9
Alteration products of actinolite	6.2
Albite	24.3
Epidote	6.1
Magnetite (+ pyrite)	4.5
	100.0

X-ray study of the rock was carried out at the Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, U.S.S.R. Academy of Sciences, by N.I. Organova; the results are shown in Table 1.

As indicated in Table 1, actinolite and albite are the chief minerals of the rock; the X-ray powder pattern for these minerals showed the strongest lines. It was impossible to decide positively whether magnetite lines are present because they may have been overlapped by the lines of actinolite and albite.

Thermal analysis has been widely used recently in the study of different minerals, especially those containing water. Differential thermal analysis can be very useful during the study of strongly deformed rocks. This was convincingly shown by P.P. Smolin [1] during his investigation of porphyrite as it changed into a mixture of kaolinite, carbonate, and muscovite.

Although the rock sample studied has a fresh appearance and a massive texture, it contains the minerals actinolite and albite with chemically combined water. Consequently, we applied thermal analysis to the study of this problem. The curves of heating and cooling were obtained in the laboratory at high temperatures by A.L. Tsvetkov.

Figure 2 is the curve of rock heating. Endothermic reaction (980-1.030°), in accord with the conclusions of D.S. Belyankin and Ye.V. Donskaya [1], is believed to indicate the disintegration of actinolite with evaporation of water of crystallization. At low temperature and endothermic reactions at 620-660°, the possibility of the presence of an alteration product of actinolite is not excluded (an isotropic, opaque, green area within actinolite grains was present). Reaction at such temperatures with a chloride occurred. Therefore, according to A.I. Tsvetkov, the product of alteration of actinolite can be attributed to the presence of a chloride.

In thin section, some aggregates of fine-grained albite do not contain twins at all and by their morphology are very similar to aggregates of secondary quartz. In order to determine the presence or absence of quartz in the rock, the cooling curve (Fig. 3) was taken, because in washed sections and by the refractive index method, quartz was not determined. This curve shows that the sample does not have the characteristic peak which normally appears at the transition from alpha-quartz into beta-quartz at the temperature of 575°. Therefore, quartz is absent from the given sample.

The chemical contents of various rocks are represented in Table 2 (Column 2). For comparison, the chemical analyses of the following rocks are given in Table 2: 1) Albite-actinolite schist north of Khibiny tundra, and 2) Albite-actinolite schist, central Karelia. It is evident that all three samples of rock are similar in their chemical content. The closest to our standard sample is the rock from the region north of Khibiny Tundra. This analyis was made by Ye. Sverzhinskaya and published by B.M. Kupletskiy [5]. A thorough study of published literature on the petrography of the Kol'skiy Peninsula has shown that albite-actinolite schist is not found north of the Khibiny alkalic massif. South of Khibiny Tundra it is present in many places. Evidently, into an error somehow slipped this work of Kupletskiy.

Chemical analysis of Sample 433-a shows that it contains less lime than the sample analyzed by Ye. Sverzhinskaya. The total quantity of iron oxides of all types in this sample is about the same, as in our sample but our sample has considerably less iron

Table 1

The results of X-ray study of Sample 433-a[1]

No. lines	Experimental data		Data from textbook					
			Actinolite		Albite		Magnetite	
	I	d_α	I	d_α	I	d_α	I	d_α
1	3	4,01			5	4,11		
2	2	3,76			1	3,81		
3	2	3,64			2	3,70		
4	4	3,51			4	3.55		
5	2	3,38	6	3,42	1/2	3,40		
6	10	3,20			10	3,21		
7	7	3,13	9	3,14				
8	5	2,96	6	2,938	5	2,955	6	2,99
9	2	2,82	5	2,79			5	2,807
10	6	2,71	10	2,705				
10A	2	2,61	6	2,595				
11	8	2,53	8	2,54	3 1/2	2,554	10	2,541
11A	1	2,43			3	2,44	3	2,428
11Б	1	2,39	2	2,404				
12	1	2,34	7	2,32	3	2,31		
13	3	2,17	8	2,155				
14	2	2,01	7	2,008	3	2.013		
15	6	1,891			4 1/2	1,887	2	1,884
16	2	1,827			4 1/2	1,821		
17	3	1,785			3 1/2	1 777	4	1,785
18	1	1,754			2 1/2	1.745		
19	2	1,718			3	1 714		
20	1	1,653	8	1,642	2	1,663		
21	4	1,622	3	1,614				
22	2	1,587	8	1,578	1 1/2	1,581		
23	2	1,542	3	1,551				
24	4	1,489	9	1,507	3	1,500	9	1,479
25	5	1,445	10	1,432	4 1/2	1,457		
26	1	1,298	8	1,292				
27	2	1,284			3	1,278		
28	2	1,271			1 1/2	1.266		
29	2	1,150			2	1,163		
30	2	1,090			1	1.089	8	1,091
31	7	1,051	10	1,046	1 1/2	1,052	6	1,047

[1]Sample was prepared by the powder method on the tube with the iron anode at a tension of 35,000 Kv and 10mA and 50 hours of exposure. Data are taken from the textbook: V.I. Mikheyev and A.N. Dubinin, Roentgenometric determination of minerals. Gostekhizdat, 1939.

oxide and more iron peroxide. The abundance of ferric oxide in Sample 433-a is clearly shown in the optical data covering the more pronounced ferrous character of rocks such as actinolite and epidote.

As noted above, Sample 433-a shows distinct crystalline schistosity and elongation of minerals in one main direction.

This rock can be called granonematoblastic in texture with its linear, parallel features [9]. By mineralogic and chemical composition it is an albite-actinolite crystalline schist. This texture is usual for metamorphic rocks.

N.I. Soustov, who studied rocks of the Imandra-Varzuga formation for several years, speaks of the origin of albite-actinolite schist in the following way in one of his works on this region:

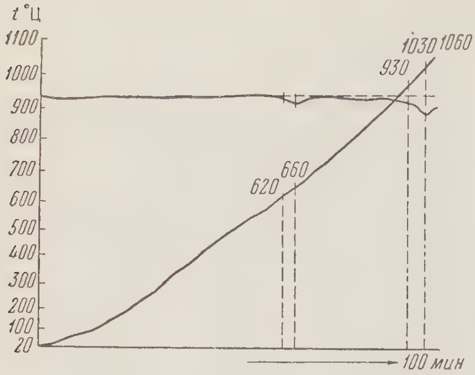


Fig. 2. The curve of heating of Albito-Actinolite Melt, Sample 433-a.

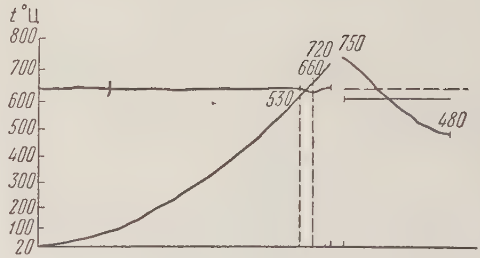


Fig. 3. The curves of heating and cooling of Albite-Actinolite Schist, Sample 433-a.

"The origin of albite-actinolite schist as the result of metamorphism of igneous rock cannot be doubted, because it is very commonly related to distinct transitions to amygdaloid, diabase, etc. Its origin is due to dynamometamorphic changes in these rocks during which the rocks have undergone granulation, grinding, and rolling with the resulting development of felted structures, and the development of lenses filled with amphibole, epidote, and albite." ([13], p. 48).

Further, he notes that "in their extreme types such schists, because of the strong process of chloritization, change into pure albite-chloride schist, free of amphibole." These schists have been thoroughly studied

Table 2

Chemical Content of Certain Metamorphic Rocks from Kola Peninsula in Karelia (in percent)

Oxides	Albite-Actinolite Schist, Sample 433-a	Albite-Actinolite Schist of North of Khibiny Tundra	Albite-Actinolite Schist, Central Karelia
SiO_2	52,06	50,32	59,42
TiO_2	1,34	1,94	0,29
Al_2O_3	13,00	12,34	11,19
Fe_2O_3	7,34	2,66	3,51
FeO	6,04	10,35	6,57
MnO	0,14	0,35	0,18
CaO	5,48	8,44	6,49
MgO	7,68	6,57	5,94
SrO	—	0,01	—
K_2O	1,00	0,36	2,62
Na_2O	4,81	3,27	2,68
P_2O_5	—	0,14	—
S	—	0.04	—
H_2O	0,20	0,31	0,12
П.п.п.	1,00	2.75	1,39
Total	100,09	99,85	100,40

Note: Comma represents decimal point.

by N.I. Soustov, although albite-actinolite schist is described by him only in a general way.

A brief description of albite-hornblende and hornblende-chlorite schist bordering the Khibinskiy massif of alkalic rock on the southwest and south and possessing nematoblastic or porphyroblastic texture is given in the article by N.A. Yeliseyev, I.S. Ozhinskiy, and Ye. N. Volodin [2]. N.G. Sudovikov [14] has found greenstone in different stages of metamorphism and closely related to each other during geologic mapping of central Karelia (Tungudskiy and Shugezerskiy regions). He separates metadiabase green schist facies and amphibolite facies according to the degree of metamorphism.

The green schist facies includes two groups: 1) actinolite-biotite schist and 2) amphibolite schist. Albite-actinolite schist with porphyroblastic structures of biotite was subjected to chemical analysis; the results are given in Table 2 (Column 4). The biotite content of the albite-actinolite schist was 12.6 volumetric percent.

Therefore, the rock which has been studied by us is an albito-actinolite schist, having attained a medium stage of metamorphism, according to Eskola. This crystalline schist formed because of metamorphism of igneous rock. If we were to call it intrusive diabase, as do the geologists of the Kolskiy AN SSSR Affiliate it would be incorrect, because it is not an intrusive but is a typically metamorphic rock; such an incorrect opinion can be explained only by the fact that its massive character hinders its exact determination under field conditions. In discussing these rocks, M.I. Soustov [12] said that metadiabase is "usually fine-grained, greyish-green color, very dense and not distinctly stratified. Small intrusions of ore are often encountered, almost unrecognizable in the field and commonly confused with albite-actinolite schist, provided it does not have an aphanitic texture" ([12], p. 66).

Such rock determinations can be established, evidently, only after a thorough petrographic study in the laboratory.

As noted above, albite-actinolite schists are altered from the surface to a depth of 5-10 mm; this alteration on the surfaces of schistosity and in fractures has gold-like emanations which give the rock a dark-brown color.

According to study of thin sections, the rock at the weathered surface has a mineralogic content identical to the fresh part. The only difference at the weathered surface is the presence of a brick-red mineral instead of actinolite. We believe this mineral to be pseudomorphic after actinolite, because it is undoubtedly an alternation product of actinolite. Coarse grains of the pseudomorphic central region are isotropic; they are dark green and their refractive index is $N = 1.688 \pm 0.003$. According to the number of indices of refraction, the central part of the grain can be identified as the altered actinolite. The color on the border region is brick-red; it is strongly refractive, and immersed samples have a distinct pleochroism (Ng = dark-brown; Np = greenish blue). Optical constants of the brick-red mineral are the following: $Ng = 1.705 \pm 0.005$; $Np = 1.657 \pm 0.003$; $Ng\text{-}Np = 0.048$; $(-)\ 2V = 70^{\circ}$.

Studies of thin sections and immersion studies have shown that the original actinolite of the rock underwent strong ironization on the surface. This is strongly expressed in the change of its optical properties, as shown by the mineral pseudomorphic after actinolite.

Finer grains are fully transformed into a mineral of brick-red color having homogeneous appearance. It is characteristic that only thin needles of actinolite, which are inside the albite aggregates, have preserved their original state.

Albite and epidote in the surface areas are not affected at all by the process of alteration; this fact is established by a constancy in their light refraction data.

We attempted to determine what this new mineral on the surface region really is. To solve this identification problem we used X-ray and thermal analysis methods.

It is necessary to say that the petrographer studying rocks from the Imandra-Varzuga formation considered that this goldish mineral is biotite, or rather the iron-bearing variety, lepidomelane.

Thermal analysis of the surface region of the albite-actinolite schist indicated the presence on the heating curve of a kind of endothermic limit between 990 and 1040°. This limit corresponds to the disintegration of actinolite with the emanation of water of crystallization. According to A.I. Tsvetkov this endothermic reaction can in no way correspond to that of biotite.

Many investigators have shown that green hornblende, while heated in the presence of air, changes into the brown variety having optical constants similar to basaltic hornblende. Optical properties of the brick-red mineral are close to those of basaltic hornblende, but since this pigment is absent, the identification of mineral as basaltic

Table 3

Results of X-ray Study of the Surface Section of Albite-Actinolite Schist

No. of lines	Experimental data		Data from handbook (hornblende)		No. of lines	Experimental data		Data from handbook (hornblende)	
	I	d_α	I	d_α		I	d_α	I	d_α
1	7	3,98			13	3	1,643	8	1,645
2	2	3,63			14	3	1,605		
3	8	3,50	4	3,44	15	4	1,579	8	1,574
4	10	3,16	9	3,15	16	1	1,528	5	1,529
5	7	2,93	5	2,97	17	1	1,455		
6	8	2,69	10	2,71	18	5	1,434	10	1,436
7	7	2,52	8	2,539	19	3	1,349	8	1,334
8	1	2,43	1	2,396	20	4	1,278		
9	1	2,33	6	2,326	21	4	1,267		
10	2	2,16	8	2,155	22	4	1,224		
12	1	1,778			23	2	1,193	6	1,195

Note: Comma represents decimal point.

hornblende is also precluded.

X-ray analyst N.I. Organova concludes, however, that this mineral is from the hornblende group.

To solve the identification problem of this pseudomorphic mineral, it was necessary to isolate it from the rock and study it thoroughly. It was already certain that this mineral was not a biotite. At this point, therefore, it was only possible to call it the alteration product of actinolite of the original rock, caused by the action of atmospheric agents. We purposely avoided the term "weathering" here because we consider it incongruous in this case.

Alteration of Albite-Actinolite Schist during Heating

Samples 40 cm long and 15 to 20 cm wide were taken from albite-actinolite schist and roughly shaped into blocks. These blocks were used to line the walls of a lime kiln. The heating in the furnace (or kiln) was accomplished only by wood.

A block 30 cm long, 25 cm wide, and 3.5 to 10 cm thick was taken from the wall of the furnace approximately 160 to 170 cm from its bottom.

As noted above, during the operation of the lime kiln, the block of albite-actinolite schist underwent marked changes with the formation of three colored zones: 1) grey, 2) brown, and 3) chocolate brown. The greatest change took place on the hottest surface of the block and in development of small cavities filled with a fine-grained material of light grey color.

Grey Zone (Sample 433-b). Its length ranges between 8 and 10 cm; the border with adjacent unaltered rock is indistinct; fractures are apparent and highly developed, but pores are absent. The fracture of the grey rock is very similar to that of the original rock.

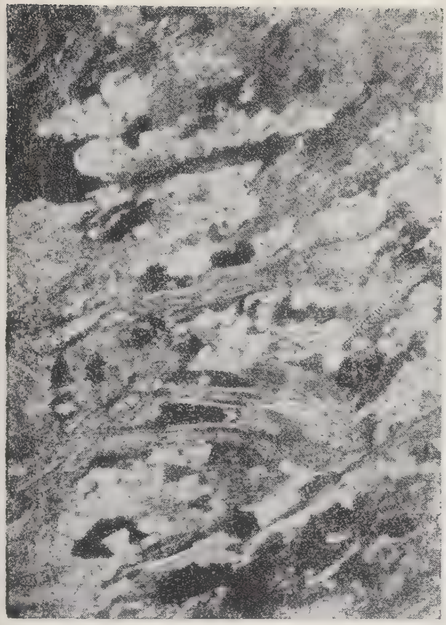
The study of the grey zone in thin section showed that the mineralogic content is the same as unaltered rock. The only difference is a gradual alteration of actinolite, whose coarse aggregates and crystals are segregated into separate filaments, and squeezed and bent at the ends (Fig. 4). The refractive index is noticeably higher but double refraction is lower. The following refractive indices were determined for the great aggregate of actinolite from the central portion of the zone in the washed out section. $Ng = 1.677 \pm 0.003$; $Np = 1.644 \pm 0.004$; $Ng\text{-}Np = 0.0\overline{1}3$; (+) $2V = 62^\circ$.

In the actinolitic filaments, pleochroism disappears. In peripheral, lighter sections, birefringence is absent, and the filaments are almost isotropic. Therefore, we must consider as significant the strong changes of the optical properties of actinolite.

In the sections of the grey zone close to the brown zone, even greater alteration in actinolite aggregates was observed; they are browner and somewhat ironized.

Data on X-ray study of the grey zone is given in Table 4.

According to N.I. Organova, it follows that the grey zone consists of albite, diopside, and hematite. According to the X-ray,



ig. 4. Albite-actinolite Schist After Heating. rey Zone. Sample 433-b, magnified 76X, without analyzer.

actinolite is absent in this zone. L.N. Ovchinnikov, A.S. Shur, and N.T. Yel'kina [8] arrived at the same conclusion as a result of thermal analysis of amphiboles from several scarn zones of Ural.

Optical properties of altered actinolite are different from diopside; since the alterations are inside the actinolite aggregates, it is justifiable to call this product of alteration pseudomorphic actinolite.

In the grey zone, epidote is strongly altered, becoming brown to almost transparent, and in the thin section it is hardly different from the ore mineral. A.F. Korzhinskiy [4], during the thermal analysis of epidote, observed such phenomenon at a temperature of about 800-900^{o}.

Judging from the X-ray data, we may say that the presence of hematite testifies to the oxidation of magnetite in the grey zone and its ultimate transformation into hematite. Absolutely unaltered and fresh remains in the zone consist only of albite.

A characteristic peculiarity of the grey zone is its structural resemblance to the unaltered rock in spite of strong alteration of the minerals composing this zone. It is also necessary to note the very gradual alteration of minerals toward the hot end of the block and the absence of the distinct border with an unaltered zone. Because of the same peculiarities, the grey zone is believed to be transitional.

Brown Zone (Sample 433-b). The grey zone quite distinctly changes into brown, characterized by density and a baked appearance. The length of this zone is about 2-3 cm. It already has separate, closed pores up to 0.5 mm long.

The brown zone, in terms of mineralogic composition and structure, hardly differs from the preceding two zones. The linear-parallel texture disappears, and an insignificant quantity of the glassy phase starts to appear, testifying to the initiation of a rock melting stage. Pseudomorphs after actinolite become smaller in size -- not over 0.08 by 0.35 mm, 0.04 by 0.06 mm prevailing. The refractive indices of the pseudomorph greatly increase, namely: $Ng = 1.712 \pm 0.003$; $Np = 1.689 \pm 0.003$; $Ng - Np = 0.023$.

The X-ray proved again that these mineral zones are diopside. It is necessary to note that in the grey zone of pseudomorphism, the refractive indices are lower than those of diopside occurring in the brown zone. It is possible that in diopside of the brown zone, there is an isomorphic mixture of ferric oxide which increases with an increase in refractive index. In this zone, albite starts to change. Its coarse grains in the central part still retain their shape and refractive index, but the edges had started to melt. Smaller grains of albite are greatly changed and are transformed into aggregates of a fine-grained plagioclase with a refractive index of: $Ng = 1.546 \pm 0.002$ and $Np = 1.538 \pm 0.002$. These figures are greatly different from optical constants of albite and indicate the formation of plagioclase of the oligoclase type.

Between the coarse grains of albite and the pseudomorphic actinolite sections are filled with yellow glass with N equal to 1.535-1.540. Refraction of the glassy phase permits one to conclude that it is chemically complex. This glass, occurring in small needles and simple twins of plagioclase, has the following indices of refraction: $Ng = 1.565 \pm 0.002$ and $Np = 1.556 \pm 0.003$. These data correspond to those of labradorite. Some of the needles of plagioclase are semi-synthetic twins, but due to their very small dimensions, the law of twins was not determined. Dimensions of needle aggregates of labradorite range between 0.001 by 0.010 and 0.015 by 0.180 mm; needles 0.005 by 0.08 mm long prevail.

The ore mineral of the grey zone, hematite, began to melt, and it is possible that to a certain degree it entered into the com-

Table 4

Results of X-ray Study of the Grey Zone

No. of lines	Experimental data		Data from the handbook					
			Albite		Diopside		Hematite	
	I	d_α	I	d_α	I	d_α	I	d_α
1	6	4,04	5	4,11				
2	4	3,66	2	3,70				
3	1	3,52	4	3,55				
4	10	3,20	10	3,21				
5	7	3,02			10	3,00		
6	5	2,93	5	2,955				
7	1	2,78						
8	5	2,70					10	2,69
9	8	2,52	3 1/2	2,554	10	2,52	10	2,518
10	5	2,13	3 1/2	2,116				
11	2	2,03	3	2,013				
12	3	1,835	4 1/2	1,821			10	1,834
13	4	1,785	3 1/2	1,777				
14	2	1,754	2 1/2	1,745	7	1,74		
14A	1	1,707					10	1,688
15	5	1,631			10	1,616		
16	6	1,486	3	1,500			9	1,483
17	1	1,417	3 1/2	1,425	9	1,418		
18	4	1,352	5	1,347				
19	3	1,285	3	1,278				

Note: Comma represents decimal point.

position of the yellow glass. Dark aggregates of ferric oxide, with prevailing dimensions of 0.05 by 0.08 mm, appear near the regions filled with glassy phases. Closer to the next hot zone, the crystallization of labradorite increased and small crystals of secondary magnetite 0.01 mm long appear. This region of the brown zone is represented in Fig. 5.

Data of X-ray analysis of the brown zone are given in Table 5.

The data of Table 5 coincide well with the results of the microscopic study of the brown zone indicating the presence of albite, labradorite, diopside, and hematite. It is characteristic that all strong lines of labradorite were observed. In comparison with the grey zone, the lines of hematite here are not so abundant.

The heating curve for the brown zone did not show any reaction up to 1,080°, which testifies to the full development of the minerals containing water in the grey zone; at the same time, the new formations which could appear were not expressed thermally.

Therefore, the brown zone is characterized by the prevalence of altered minerals in the solid state; but the appearance of glass phases suggest the beginning of mineral melting. Refractive indices of the glass phase prove it to have a complicated silica composition. The presence of labradorite in the brown zone can be explained as follows: 1) Penetration of a certain amount of lime from the working space of the oven into the melt from which, during cooling, the needles of labradorite crystallized; or 2) formation of the melt on account of lime-bearing minerals of the original rock, i.e., epidote and actinolite (5.48 percent CaO). The second concept seems most reasonable.

The grey and brown zones of albite-actinolite schist are altered at the surface of the zone of brick-red color in two depths, at 10 and 15 mm. This zone or region is a highly oxidized surface of the rock. In the thin sections from this region, two phases are visible: albite and dark brown, almost black material. The latter includes ore minerals and greatly altered forms of ironized grains of actinolite and epidote. Special

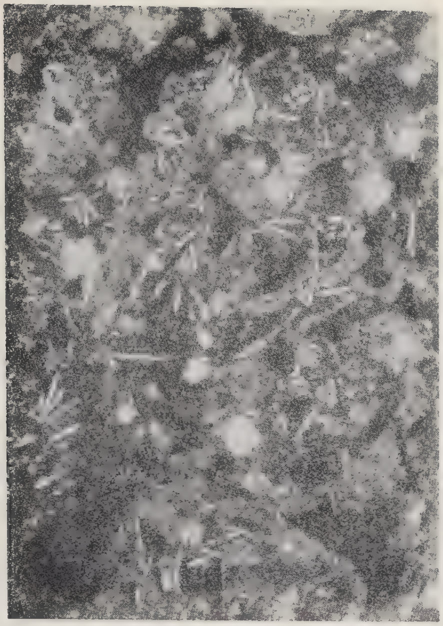


Fig. 5. Albite-actinolite Schist After Heating. Brown zone. Sample 433-c, magnified 76X, without analyzer.

chemical analysis showed the presence in this section of 13.70 percent Fe_2O_3 compared to 7.34 percent of Fe_2O_3 in the fresh rock. This data confirms the strong oxidation of the surface region of the block of rock. Unfortunately, it remains unknown whether this oxidation occurred during the operation, or whether it was caused by the action of atmospheric agents after furnace heating. Quite possibly, the alteration of surface regions of the block was stimulated by both factors.

X-ray investigation has found a greater quantity of the following minerals in the red-brown region over the grey region: albite, labradorite, diopside, and hematite; the most characteristic strong lines are observed for hematite. On the heating curve, no reaction was observed up to 1,100^{o}.

Chocolate Brown, Porous Zone (Sample 433-d) has a dense, baked structure and is about 2 cm long. It is characterized by the presence of a great quantity of small and large pores, the largest 3 mm across. The border with the brown zone is sufficiently distinct. The hot surface facing the working space of the oven was greatly melted, smooth and lustrous; its color is dark. In places at the surface there are depressions frớm 1 to 3 mm (cavities filled with light grey, fine-grained material).

Table 5

Brown Zone, Results of X-ray Study

Line No.	Experimental Data		Handbook Data							
			Albite		Labradorite		Diopside		Hematite	
	I	d_α	I	d_α	I	d_α	I	d_α	I	d_α
1.	1	4,04	5	4,11	3	4,13	—	—	—	—
2	3	3,53	4	3,55	3 1/2	3,55	—	—	—	—
3	10	3,18	10	3,21	10	3,22	—	—	—	—
4	8	3,00	—	—	—	—	10	3,00	—	—
4^A	6	2,95	5	2,955	4	2,948	—	—	—	—
5	8	2,77	—	—	—	—		—	—	—
6	10	2,52	3 1/2	2,55	5	2,53	10	2,52	10	2,510
6^A	1	2,47	3	2,446	1/2	2,448	—	—	—	—
7	3	2,29	3	2,31	1/2	2,29	—	—	—	—
		2,14 }	—	—	—	—	—	—	—	—
8	Twin.	2,10 }	3 1/2	2,116	3 1/2	2,129	—	—	—	—
9	2	2,03	3	2,013	2	2,014	—	—	—	—
9^A	1	1,937	—	—	—	—	—	—	—	—
9^B	1	1,840	2	1,846	5	1,824	—	—	10	1,834
10	5	1,752	2 1/2	1,745	5	1,766	7	1,74	—	—
11	4	1,622	—	—	—	—	10	1,61	—	—
12	7	1,489	3	1,500	3	1,485	—	—	9	1,483
13	6	1,418	3 1/2	1,425	1 1/2	1,420	9	1,42	—	—
14	4	1,353	5	1,347	5	1,346	—	—	—	—
15	3	1,323	1 1/2	1,322	3 1/2	1,316	—	—	—	—
16	2	1,278	3	1,278	1 1/2	1,284	—	—	—	—

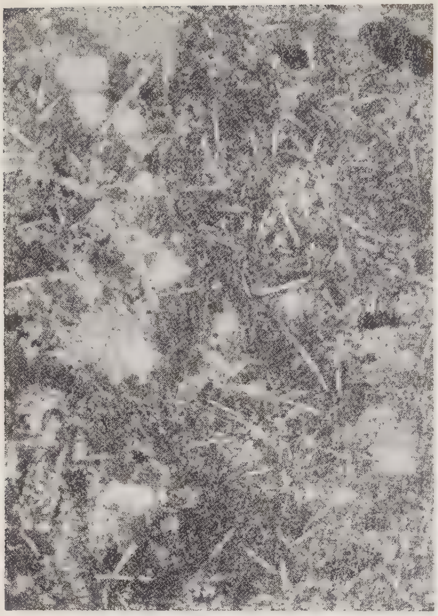


Fig. 6. Albite-actinolite Schist After Heating. Chocolate brown zone. Sample 433-d, magnified 76X, without analyzer.

Fig. 7. Albite-actinolite Schist After Heating. Chocolate brown zone. Sample 433-d, magnified 165X, reflected light.

Strong changes in the chocolate, dark brown zone are visible in thin section; all minerals of the original rock are altered.

The most resistant mineral of the rock, albite, completely disappears in this zone; presumably, it melted and entered the glassy phase, which is, in this zone, more homogeneous than the preceding brown zone.

Refractive index of the glass phase is $N = 1.550 \pm 0.003$. As previously known, the incongruent temperature of melting of the alkalic feldspar is about 1,170°. G.A. Kovel'man [3] studying the glassification of feldspar during the roasting of ceramic material, has noticed that feldspar, in the presence of additives, begins to melt at 1,070 to 1,100°. He explains this eutectic phenomena

Table 6

Results of X-ray Study of the Chocolate Brown Zone

No. of lines	Experimental data		Data from handbook							
			Labradorite		Albite		Diopside		Magnetite	
	I	d_α	I	d_α	I	d_α	I	d_α	I	d_α
1	2	3,52	3 1/2	3,55	4	3,55	—	—	—	—
2	7	3,32	—	—	—	—	—	—	—	—
3	10	3,20	10	3,22	10	3,21	—	—	—	—
4	6	2,97	4	2,948	5	2,955	10	3,00	—	—
5	3	2,77	—	—	—	—	—	—	—	—
6	10	2,52	5	2,534	3 1/2	2,554	10	2,52	10	2,54
7	2	2,13	3 1/2	2,129	3 1/2	2,116	—	—	—	—
8	2	1,752	5	1,766	—	—	7	1,74	—	—
		1,631	—	—	—	—	—	—	—	—
9	4	1,612	—	—	—	—	10	1,616	9	1,612
10	6	1,481	3	1,485	3	1,500	—	—	9	1,479
11	2	1,419	1 1/2	1,420	3 1/2	1,425	9	1,418	—	—

by the presence of a mass of oxides playing the role of fluxes. For the mineral heating curve in the temperature zone of 1,100 to 1,120°, melting with partial appearance of the glassy phase, is apparent.

Therefore, by different methods, but with good coincidence, it was shown that the melting of albite into the glassy phase occurs at a temperature of about 1,100°.

Pseudomorphic actinolite in this zone, bordering the brown zone morphologically, is not different from the later brown zone (Ng = 1.714; Np = 1.694). In the hotter region of the zone it was melted and became smaller in size, giving a part of its material to the glassy phase.

The quantity of labradorite increases noticeably; it crystallized during the cooling from the melt and is permanently contained in the glassy phase. The dimensions of its crystals in this zone increase and range between 0.001 by 0.010 and 0.02 by 0.20 mm. Together with labradorite in the hotter zones, new groups of small crystals of colorless pyroxene appear with refractive indices of Ng = 1.728 and Np = 1.710.

Ferric oxides are also present inside the glassy phase forming separate aggregates and small cubic crystals of secondary magnetite with a prevailing diameter of 0.008 mm are also present. They partly enter into the composition of glass, in places giving it a yellow color.

The microstructure of the middle portion of the chocolate brown zone is represented in Fig. 6. The narrow light prisms and needles in the photo are labradorite. In Fig. 7, a greater portion of this zone is represented. The crystals of labradorite and pyroxene (light grey) in the glassy phase (dark grey, intermediate mass) are represented in the photo, under reflected light; bright, light cubes and the aggregate is a secondary magnetite. Data on X-ray study of the chocolate brown zone are given in Table 6.

The X-ray patterns of this zone do not indicate hematite, but show only the presence of magnetite, coinciding well with microscopic observations. Since the majority of the experimentally obtained X-ray lines correspond closer to labradorite than albite, the mineral is probably labradorite rather than albite, hence in this zone we have only one labradorite. The presence of a considerable quantity of the glassy phase in the chocolate brown zone shows that this zone had reached a very soft and partly melted stage. The vast quantity of large and small pores can be explained as: a) liberation of the water vapor exactly in this zone where it could escape from the grey zone through the microfissures formed as a result of the decomposition of water-bearing minerals, actinolite and epidote; b) melting of the large grains of albite and the resulting development of the glassy phase which commonly surrounds the pores.

A considerable increase in the quantity of labradorite testifies to the fact that in spite of enrichment by albite, this melt has received enough energy from the working space of the oven to achieve crystallization of the labradorite during the cooling of melt.

In the vicinity of the coarsest surface of the block of rock, close to the cavities, the fabric consists of an accumulation (in thin section) of entirely undisturbed grains of quartz and albite.

Evidently this foreign material has entered the softened surface of the hot zone and remained in it. Its origin we do not know. Part of this material, unfortunately, was calculated as part of the sample during chemical analysis, thus giving a higher silica content for the chocolate brown zone than it initially had.

Mineralization in cavities and contact interlayers on the hot surface of the albite-actinolite schist

As noted above, pits or cavities on the hot surface of the chocolate dark brown zone are filled with a fine-grained light-colored powder, which has been baked into quite a strong substance. A series of interlayers with characteristic minerals are present in this substance in the chocolate-dark brown zone; these minerals permit us to consider that the interlayers represent a small-scale type of scam.

In Fig. 8, a contact between the chocolate dark brown zone (left part of the photograph, with two coarse pores) and a cavity filled with a fine-grained substance is shown (dark spots in the right part of the photograph).

The fine-grained light grey substance filling the cavities reacts actively to weak hydrochloric acid by giving off bubbles of CO_2. In immersion samples, it is a very dispersed material showing distinct anistotropism under polarized light and having a refractive index corresponding to calcite (No = 1.658). X-ray study of the powder has confirmed that it is calcite (Table 7).

Calcite in cavities, undoubtedly, is of secondary origin. This mineral is commonly

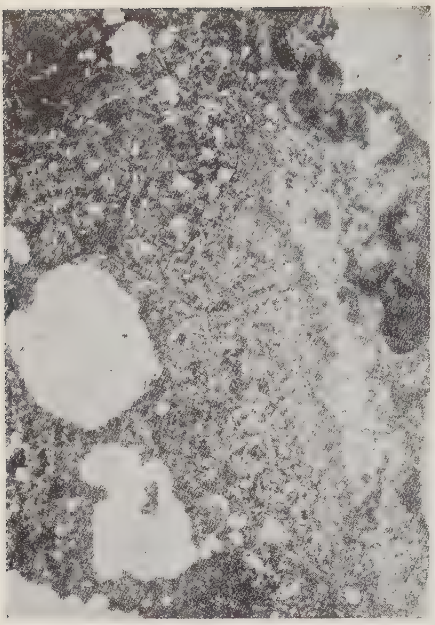


Fig. 8. Contact between the chocolate brown zone of the albite-actinolite schist (left half of the photo) and cavity with calcite (dark spots on the right part of the photo). Magnified 25X, without analyzer.

formed when free lime is present in liquids. Gradually, after hydrolysis under the influence of atmospheric moisture, calcium anhydride absorbs carbon dioxide from the air and becomes an aggregate of finely aggregated calcite. Secondary calcite appears dark in the film due to greater dispersion. After studying the aggregates of secondary calcite in the chocolate brown zone, we noted several contact layers due to the interaction of calcite with components of the rock.

Table 7

Data on X-ray Study of Light-grey Powder from A Cavity

No. of lines	Experimental data		Data from handbook	
	I	d_α	I	d_α
1	7	3.32	–	–
2	10	3.02	10	3.03
3	3	2.48	4	2.49
4	3	2.28	6	2.28
5	4	2.10	6	2.10
6	3	1.908	8	1.920
7	3	1.875	7	1.870

The nearest interlayer consists of well-developed prismatic crystals of slightly birefringent melilite; some of its aggregates are zoned. At its outer part, the melilite has a refractive index, No = 1.648; Ne = 1.644; No grows to 1.652 while Ne remains constant in the outer part. In close proximity to the melilite, brightly birefringent pseudowollastonite (Ng = 1.649; Np = 1.610) and separate grains of greyish spinel occur. The microstructure of this interlayer can be seen in Fig. 9.

The melilite-like minerals are equivalent to a solid solution of ochermanite and galena according to the optical constants, about 50 percent being derived from each component.

Further, the layer is composed of yellow-green pyroxene, with refractive indices of Ng = 1.735 and Np = 1.723, and of colorless glass in interstices between the crystals with indices of N = 1.520-1.530. Twins of pyroxene crystals 0.01 by 0.08 mm to 0.15 by 0.90 mm, are represented in Fig. 10.

The last interlayer bordering the chocolate brown zone consists of colorless pyroxene with refractive indices of Ng = 1.725 and Np = 1.710 (See Fig. 11). Together with pyroxene are the aggregates labradorite, which have the following indices of refraction: Ng = 1.566 and Np = 1.557.

Therefore, in a very thin layer (0.5-1 mm) between the hot chocolate brown zone and calcite cavity, contact metamorphic interaction of lime, from the working space of the furnace has taken place with the rock. This resulted in the formation of three interlayers, one melilitic and two pyroxenic, which can be regarded as a type of scam. The reaction occurred in the solid phase, evidently, but with the presence of liquid in large quantities.

Chemical Data

The original rock of dark green color, and the brown, and chocolate brown zones of the block were subjected to chemical analysis after service in the furnace; the results are in Table 8.

The comparison of the chemical analysis of the initial rock and the rock from the two hot zones of the furnace, showed a great resemblance in chemical content. This striking uniformity confirms our supposition that in this zone, reactions in rocks take place basically in the solid state due to redistribution of oxides in the rock itself, without considerable addition of new material from outside. In fact, all the following oxides -- SiO_2, TiO_2, Al_2O_3, MnO, MgO, Na_2O and

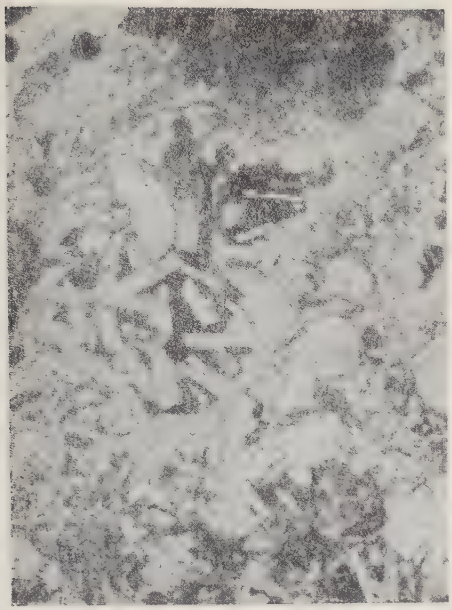


Fig. 9. Melilite interlayer between the chocolate brown zone and calcite cavity. Magnified 76X, without analyzer.

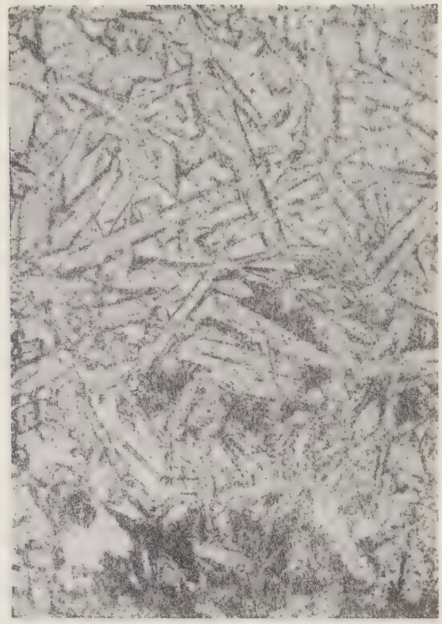


Fig. 10. Interlayer of yellowish-greey pyroxene between the chocolate brown zone and calcite cavities. Magnified 90X, without analyzer.

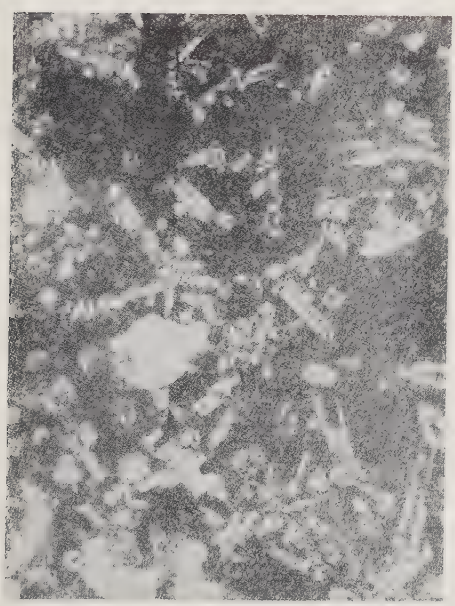


Fig. 11. Interlayer of colorless pyroxene adjacent to the chocolate brown zone. Magnified 76X, without analyzer.

K_2O -- are in about the same proportion in these zones. A slightly larger amount of SiO_2 in the chocolate brown zone is explained by the presence of quartz which fell into the softened, hot surface.

It is characteristic that in the brown and chocolate brown zones water is absent (above 110^{o}), which agrees well with the data from microscopic and thermal analysis of this zone. The diminution of ferric oxide in the chocolate brown zone, probably, is of local significance and is due to heterogeneity of the original rock. In the chocolate brown zone, little accumulation of lime is observed; this suggests that the lime migrated into this zone from the working space of the furnace.

Of deep interest is the chemical composition of the light grey, fine-grained powder from the cavity. It contains a relatively large amount of silica (28.00 percent), testifying to the presence in the analyzed material not only of the cavity filling, but also of wall material; i. e., the intermediate thin interlayers.

The presence of a considerable amount of lime and the loss during heating of CO_2 confirm the secondary origin of the material in the cavities. In regard to other oxides (SiO_2, Al_2O_3, MgO, CaO and others), their presence

Table 8

Chemical content of albite-actinolite schist of the hot zone of the block and the light-colored powder in cavities (in percent)

Name of Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O^-	H_2O^+	П.п.п.	Сумма
Original rock, Sample 433-a	52,06	1,34	13,00	7,34	6,04	0,14	7,68	5,48	4,81	1,00	0,20	1,00	—	100,09
Brown zone, Sample 433-b	53,02	1,34	14,32	8,38	4,91	0,14	7,68	4,32	4,80	1,00	0,12	Нет	—	100,03
Chocolate brown zone, Sample 433-c	55,72	1,30	13,40	6,64	4,91	0,14	7,04	5,80	4,40	0,90	0,08	Нет	—	100,33
Light colored powder from a cavity	28,00	0,50	4,33	5,17	—	0,04	2,92	37,46	1,76	0,38	1,33	—	17,83 (CO_2)	99,72

Note: Comma represents decimal point.

is in accord with microscopic data according to which a variety of melilite, pseudowollastonite, pyroxene, and greenish spinel with a little of the glass phase are present.

Conclusion

The factual material given above is interesting from two points of view: a) in determining the character of changes albite-actinolite schist underwent during heating and b) in determining the value of crystalline schist as a natural, fire-resistant material for the lining of lime kilns.

During the heating of albite-actinolite schist in the lining of the furnace, it went through several great changes; actinolite was altered to a pseudomorphosic mineral, which according to X-ray patterns is diopside. Magnetite became hematite through oxidation. The most resistant was albite which underwent flux only in the hottest chocolate brown zone. New minerals were formed: feldspar of labradorite type and a different pyroxene crystallized from the melt during cooling. Very interesting mineralization at the contact of the lime furnace charge and the rock, with the appearance of interlayers of melilite and pyroxene, occurred.

According to the published experimental work and my own observations on the changes of minerals, we can say that the following temperatures developed in the region of the block emplaced in the lining of the furnace were: in the grey zone -- 800°, in the brown zone -- 1,000°, and in the chocolate brown zone -- 1,100°. These approximate temperatures testify to the good heat conductivity of the rock. The material obtained by us is possibly of great interest for petrologists as an example of interaction of metamorphic rock with lime at a relatively high temperature (1,000 to 1,100°) under normal pressure.

The second part of the problem consists of the fact that schist has been used as a natural refractory lining material in a lime kiln. It is known that for disintegration of lime at atmospheric pressure it is enough to heat it to 900-910° and keep it at that temperature for some time. However, for quicker transfer of heat from the hot gases to the pieces of lime, the temperature in the furnace has to be increased to 1,100-1,200°, as was shown by B.G. Skramtayev, N.A. Gerlivanov, and G.G. Mudrov [10].

Therefore, in the absence of true refractory materials, in certain cases, it is possible to use blocks of rock as a substitute. It is interesting to watch the behavior of such a lining in operation and keep in mind the above mentioned ideas of F. Yu. Levinson-Lessing.

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SELENIUM AND TELLURIUM IN DEPOSITS OF DIFFERENT GENETIC TYPE

by

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Investigations of recent years have shown that selenium and tellurium, the chemical analogues of sulfur, are related to a group of dispersed elements having many of their own minerals (tellurium 40, selenium 37), that form as the result of almost every type of mineralization processes from magmatic to sedimentary. Because of its close relation to the chemical and crystallographic properties of sulfur, selenium is formed chiefly by hypothermal processes with sulfides and enters isomorphically into their structure.

Only in the absence of sulfur or where it is especially deficient does selenium form its own minerals.

However, tellurium possesses chemical and crystallographic properties considerably different from sulfur but is concentrated together with selenium and sulfur at the same stage of mineralizing processes and always or almost always forms its own minerals, chiefly with elements of high atomic numbers (Au, Ag, Pb, etc.). If some dissemination of tellurium takes place in sulfides it is only to a very small degree.

Usually, the Clarke index of selenium is $8 \cdot 10^{-5}$ percent, and of tellurium is $1 \cdot 10^{-6}$ percent. As shown by our experiments, the Clarke index of selenium for rocks of the U.S.S.R. is $1.4 \cdot 10^{-5}$ percent. In several deposits, chiefly sulfides, the average selenium content is expressed in hundredths and thousandths of a percent, which exceeds the concentration indicated by the Clarke index hundreds and thousands of times. The same applies to tellurium.

"The accumulation of an element higher than the Clarke index corresponding to it results in the formation of a mineral deposit. And here we have a series of transitions from relatively small concentrations to accumulations which are over the limit of technical and economic utilization, i.e., the highest concentration at the given moment and under given conditions, called the pay-deposit" [4].

For these deposits, a certain chemical-mineralogic composition is characteristic, and formation of such deposits is the result of certain geologic and geochemical processes which commonly control the type of deposits for these and other mineral resources.

In the study of mineral resources we usually give a description of a certain geologic formation which is quantitatively and qualitatively suitable for industrial utilization. But the definition "deposit" and "natural resource," is very changeable and depends on the level of development of science and technology, and on the complexity of the utilization of ores.

The concept of a deposit is, above all, determined by the presence of certain resources and conditions of occurrence of one or another usable component.

Because rare elements and especially disseminated minerals are not extracted from the ores but are taken out only as a by-product, they are not a deposit in the generally accepted meaning of this term. Sharply increased demand on the rare elements because of rapid growth of technology forces geologists to search for new sources of certain rare elements, including selenium and tellurium. The present work aims to indicate sources from which it is possible to obtain selenium and tellurium, to discuss those genetic types of deposits which, from this point of view, might be interesting.

During separation and description of the types of deposits of selenium and tellurium, we have taken as a basis, first of all, the scale of magnitude of resources which could be industrially useful now or in the future.

Therefore, magmatic sulfide deposits of the Sudbury type with its selenium and tellurium measured in thousands of tons in spite of the proportionately low content of these elements in the ore and the absence of their own minerals, has been considered one of the largest types of deposits of

selenium and tellurium.

For the present, thin selenium veins of Hartz with well-expressed selenium mineralization and gold and silver telluride, from which neither selenium nor tellurium can be extracted in spite of their high concentration, are also regarded by us as deposits of selenium and tellurium. The first (veins of Hartz) because analogous formations in nature could occur on a larger scale, the second (deposits of gold telluride) because tellurium is highly concentrated and can be a source for tellurium extraction if the demand on this element increases.

Deposits of selenium and tellurium form at almost all stages of endogenic mineralization. Several deposits originated during exogenic processes; formation of a considerable part of all selenium and tellurium deposits is related to hydrothermal processes; in addition to listing the deposits of such type, we supplement the classification of mineral paragenesis by stating the industrial value.

A table is given below in which we list the types of selenium and tellurium deposits classified by us.

Because selenium does not always form its own minerals due to its ambiguous geochemical character, which puts it on the dividing line between simple and trace elements, we have especially introduced a column which characterizes the form of both elements in the ore.

As selenium and tellurium from deposits of several genetic types that have not been extracted until now, the knowledge of their quantitative distribution in ores is insufficient; therefore, it is not always possible to evaluate correctly the potentialities of such deposits. Therefore, in the table the perspective evaluation of the size of deposits is given from the abundant factual material we have on hand. Where data are insufficient, it is pointed out that the prognostication is unclear.

The classification which we have accepted, is not fully accurate, but, as any other classification, is more or less arbitrary. Nevertheless we think that, as a first attempt to systematize our knowledge, this table could be accepted and utilized during the broad prospecting and exploration work.

Magmatic Deposits

From the three types of properly classified magmatic deposits, which Zavaritskiy, A. N., distinguished because of their selenium and tellurium concentration, only the third type, i. e., liquational, is of interest. Differentiated massifs of norites are most commonly the mother rocks for these deposits. The ore deposits are usually located at the base of sills. Crystallization of sulfides took place after the rock was fully crystallized. In a series of deposits of the described type, it was noted that the system of veins, filled with sulfides, branching from the lower deposits into underlying intrusive rocks along fault planes, also cut the cooled mother rocks. There are known cases, where the veins of sulfides are connected with typically fissured tear zones, and are located over the bottom beds of scattered ores. According to their mineralization, these deposits are divided into two types of ores: continuous and scattered sulfides. Continuous sulfide ores usually are layers, streaks, veins, and brecciated zones. The dimensions of deposits usually are great; they extend from 100 meters to several square kilometers. The ore bodies of other shapes are more limited in size.

The mineral association consists usually of pyrrhotite, chalcopyrite, rutile, cubanite, violarite, sphalerite, ilmenite, valleriite, millerite, chromite, sperrylite, arsenopyrite, cobaltite, sulfur compounds of platinum, paladium and platinum, native copper, calaverite, melanite, and bessite.

The age of most of these deposits is Pre-paleozoic, more rarely Early Paleozoic and Early Mesozoic.

Selenium and tellurium are characteristic elements in these deposits which can be an important commercial source of selenium and tellurium.

Selenium content in different sulfides of studied deposits ranges from 0.002 to 00.01 percent, in some cases reaching 0.017 percent. Selenium does not form its own minerals, but enters the lattice of sulfides as an isomorphic addition. It is interesting to note that the enrichment of cuprous ores by selenium occurs, but in iron and nickel sulfides this enrichment is much poorer. In magmatic copper-nickel deposits, tellurium forms several minerals: calaverite, hessite, melanite, tellurium forms several minerals: calaverite, hessite, melanite, tetradymite. In a majority of sulfide minerals, tellurium is less than ten-thousandths of 1 percent. Its quantity is usually equal to the quantity of selenium. The highest concentration (up to hundredths of a percent) of tellurium also occurs in cuprous ores. The total tellurium content is lower than that of selenium. The ratio of tellurium to selenium ranges from 1:4 to 1:28 in different deposits, and even in different parts of the same deposit. The

Types of Selenium and Tellurium Deposits

Genetic type of deposit	Type of mineral association	For deposition of Se and Te	Morphology of ore bodies	Relation to intrusive rocks	Deposits	Age of deposit	Scale of deposit
Magmatic	Pyrrhotite-chalcopyrite, pentlandite.	Selenium in disseminated form in sulfides; tellurium forms its own minerals.	The zone of mineral deposits and breccia zones, situated in the bottom of intrusives. Cutting veins.	Basic and ultrabasic rocks.	Noril'sk, Pechenga, Monchegorsk, Sudbury.	Pre-paleozoic, seldom Paleozoic	Very large
Volcanic	A native sulfur.	Mixed crystal and sulfur.	Flows and veins.	--	Kamchatka, Kurile Islands, Hawaiian Islands.	--	Insignificant
	--	Selenite, selenate, and natural selenium.	Layers of volcanic tuff and bentonite.	--	Tuff deposits in Wyoming State, U.S.A. (Shoshone, Riverton).	Oligocene	Possibly large
Hydrothermal	Quartz-wolframite-bismuth.	Tellurium forms its own minerals; selenium in the form of isomorphic admixture in sulfide.	Tellurium forms its own minerals. Selenium in the form of isomorphic admixtures in sulfides.	Acid and ultra-acidic rocks.	Belukha and Bukuka in Transbaikal, Karaoba in Kazakhstan.	Paleozoic and Mesozoic	Unclear
"	Cassiterite-quartz-sulfide.	Forms its own metals (tetradymite, joseite, calaverite, altaite, guanajuatite, platinite)	Stockwork zones, stockworks, veins, lenses, zones of brecciation.	Acid and ultra-acid granites.	Nevskoye, Ingodinskoye, Sokhondo.	Mesozoic	Unclear
"	Chalcopyrite-molybdenite.	Selenium in disseminated form in sulfides chiefly in molybdenite. Tellurium, evidently, forms its own minerals.	Stockworks, zones of small veins and scattering, more rarely quartz ore deposits.	Moderately acid granitoids.	Kadzharan, Dastakert, Agarak, Paragachayskoye.	Tertiary Variscan	Large
"	Pyrite.	Selenium in disseminated form in sulfide. Tellurium forms its own minerals.	Lenses, deposits, bodies of irregular shape.	Deposited in effusive form. Paragenetically, probably, connected with subvolcanic intrusives.	Pyrite deposits in the Urals (Blyava, Sibay, Degtyarka), Altay (Nikolayevskoye).	Paleozoic-Mesozoic	Large or very large
"	Cobaltine-Selenite-Telluride.	Forms their own minerals (tetradymite, hessite, krennerite, clausthalite, guanajuatite).	Stockwork zones, veins.	Moderately acid granite.	Verkhne-Seymchansk, Vetrovoye, Volochek, Akdzhil'ga.	Mesozoic	Large

Types of Selenium and Tellurium Deposits (continued)

Genetic type of deposit	Type of mineral association	For deposition of Se and Te	Morphology of ore bodies	Relation to intrusive rocks	Deposits	Age of deposit	Scale of deposit
Hydro-thermal	Selenite	Selenium forms its own minerals (blockite, naumannite, clausthalite, and others).	Siderite-hematite-barite veins.	?	Pakajaca in Bolivia, Tilkerode, Lerbach, and Zorge in Harz, and San-Andreasberg, Germany.	Tertiary Paleozoic	Commonly small
"	Uraninite-Selenite	Selenium and tellurium form their own minerals (selenides of copper, lead, mercury, silver, and bismuth, silver and nickel tellurides.	Veins	Acid and moderately acid rocks	Katanga in Belgian Congo, Athabaska in Canada.	Proterozoic, Paleozoic	Possibly large
"	1) Gold-Arsenopyrite-Tourmaline	Tellurium usually forms independent minerals. Selenium occurs in the form of isomorphic admixture.	Quartz ore veins and stockwork zones.	Acid	Kochkar' in Southern Urals, Sovetskiy Rudnik in Yenisey Mountain Range, and Kommunar in Mariinskaya taiga.	Precambrian, Paleozoic	Unclear
"	2) Gold-bearing quartz	Tellurium forms its own minerals (Calaverite, altaite, hessite, tetradymite), Selenium in the form of isomorphic admixture to sulfides.	Regular, well-preserved veins.	Acid, moderately acid, rarely alkalic rocks.	Berezovsk in the Urals, Stepnyak, Dzelambet, Stalinskoye in Kazakhstan, Kalgurli in Western Australia.	Mesozoic, Cenozoic and Paleozoic	Unclear (possibly large)
"	3) Gold-Silver-Quartz-Adularia	Selenium and tellurium form their own minerals -- gold, silver, bismuth telluride. Silver and lead selenide.	Stockwork zones.	Deposited in extrusives. Associated, probably, with subvolcanic intrusives.	Redjang-Lebong, Lebong-Donok in Sumatra, Nagiag in Rumania.	Tertiary	Unclear (possibly significant)
"	Galena-Sphalerite-Quartz-Carbonate	Tellurium in the form of its own minerals. Selenium only isomorphically in sulfides.	Veins, lenses, metasomatic bodies.	Paragenetically, deposits are related to small intrusives of granite. Divided into three types according to condition of deposition:	Sodon, Zavodinskoye, Zyryanovskoye, Smirnovskoye.	Variscan Kimmeridgian, Alpine	Unclear (possibly large)

Types of Selenium and Tellurium Deposits (continued)

Genetic type of deposit	Type of mineral association	For deposition of Se and Te	Morphology of ore bodies	Relation to intrusive rocks	Deposits	Age of deposit	Scale of deposit
				1) In granite, shale, etc. 2) In volcanic sedimentary rocks. 3) In carbonate rocks.			
Hydro-thermal	Cinnabar-Antimonite	Selenium and tellurium chiefly form their own minerals. Selenium partially enters isomorphically.	Bedded deposits, veins, and stock-works.	Acid granitoids and their alkalic derivatives.	Kwei-Chou (China), Khaydarkan (Central Asia), and Monte-Amiata.	Quaternary, Recent	Unclear (possibly small)
"	Carnotite	In the form of native selenium and selenides of iron, copper, lead, and silver. Tellurium is not common.	Beds, metasomatic bodies.			Paleozoic, Mesozoic	Possibly large for selenium
Exogenic	Type of iron cap	In dispersed condition chiefly as native metal.	Iron cap with sulfide deposits.		Colorado Plateau. Maykain, Jul'yur Tau, Uchaly, Buribay, Blyava.		Possibly significant
"	Gold telluride	Tellurium forms its own minerals.	Placer deposits.		Upper Angara Deposit, Pad' Khorogocha, Malaya Chirka.		Insignificant

ratio 1:4 is characteristic of the disseminated ores. Massive ores, especially vein types, are characterized by a broader range of ratios: 1:10, 1:15, and even 1:28. The largest deposits of such types are: Noril'sk in Krasnoyarskiy Kray; Monchegorsk in Kol Peninsula; the Pechenga ore region, Murmansk Province; Sudbury in Canada; and Insizawa deposit in Africa.

Volcanic Deposits

Deposits of natural sulfur, volcanic tuff and bentonite are significant because of the presence of selenium and tellurium in volcanic emanations.

In sulfur deposits of volcanic origin a considerable selenium content and the usually small tellurium content is characteristic. Selenium evidently forms a solid solution with sulfur. Its content sometimes (in lump samples) reaches 48 percent. The sulfur from the Hawaiian Islands contains a high percentage of selenium (5.18 percent), from Lipari Islands (1.03 percent), New Zealand (0.19-0.30 percent).

In the Soviet Union, such deposits are known on the Kurile Islands but the distribution of selenium and tellurium in them has been poorly studied.

Samples of orange ore from Paramushir Island indicate 0.19 percent selenium and 0.025 percent tellurium. Samples from a fumarole of 120°C at the Mendeleyev volcano on the Kunashir Island contains 0.012 percent selenium and 0.001 percent tellurium. The orange sulfur from Mutnovskiy volcano (same island) contains 0.080 percent selenium and 0.012 percent tellurium. All together, 11 samples of volcanic sulfur from the Kurile Islands and Kamchatka (chiefly from the collection of A. Ye. Sverdlovskiy) have been analyzed; in 9 of them, from 0.0005 to 0.19 percent selenium has been found. Tellurium was also present in all 9 samples, from 0.0001 to 0.025 percent. These two elements have not been found in the sulfur-tar products in the vein sulfur on Kunashir Island.

Such deposits are usually small.

Several small deposits of selenium (7) are known in Wyoming, U.S.A. These commonly occur in beds of andesite tuff of Oligocene age, partly transformed into bentonite (Shoshone, Jaspar, and Rivertone deposits). Selenium mineralization occurs in two beds traceable for a considerable distance. Selenium is found in the water soluble form, and in the form of selenite and selenate; these deposits have not been studied in detail.

Chemical investigation has determined that the selenium content ranges from 0.003 to 0.012 percent. It is believed that these deposits were formed by volcanic fumarole activity.

Tuffaceous ash analysis of liparite from the Turomchansk sulfatara indicates the presence of 0.0007 percent selenium and 0.0001 percent tellurium.

Deposits of selenium which occur in volcanic tuff and bentonite are worthy of considerable attention.

Hydrothermal Deposits

The maximum concentration of selenium and tellurium occurs in disseminated (isomorphic) form and in the form of discrete minerals formed by hydrothermal action. Most sulfide minerals of hydrothermal deposits contain both elements as traces whose content in different minerals ranges from hundredths to ten-thousandths of a percent. The first in importance are pyrite and chalcopyrite deposits in which the ore contains selenium and tellurium as an admixture. They are also present in polymetallic deposits in smaller quantities.

The highest concentration of selenium is in silver, gold and silver and selenium veins, which are connected with subvolcanic intrusives of the type of the Mexican and Chilean deposits. High concentration of selenium and tellurium is known in several cobalt, sulfoarsenide, and arsenide deposits (Verkhne Seymchansk and Vetrovoye in Magadan Province). The presence of selenium minerals in some hydrothermal uranium deposits is known: Johanheorhenstadt, Schneeberg in Saxony [9]; Lake Athabaska Region, Canada [8]; Shinkolobwe, Belgian Congo [12].

In hydrothermal deposits of tellurium, its association with gold is characteristic; in the majority of cases tellurides are formed (Kalgurli and Kugardi deposits) in Australia, Colorado in U.S.S., Natiar in Rumania, and others). Formation of almost all known minerals of selenium and tellurium is conditioned by hydrothermal processes; the polymorphic modifications of some of these [5] have been considered as geologic thermometers by numerous investigators. Hydrothermal sulfide deposits containing hundredths and thousandths of a percent of selenium and tellurium are, together with copper and nickel deposits, the main source of industrial selenium and tellurium. Deposits of gold telluride are

potentially the largest industrial source of tellurium.

Quartz Wolframite and Bismuth Type Deposits

Several high temperature quartz-wolframite deposits with arsenopyrite, pyrrhotite and bismuth are genetically related to the oxide granites; they are also of interest with regard to tellurium. Ore bodies of such deposits occur at endo- and exo-contacts of granite intrusives and usually have the form of veins, more rarely stocks, stockworks, and pipe-shaped bodies with widely developed greisenization.

The chief minerals are quartz and wolframite; ore minerals are cassiterite, molybdenite, scheelite, bismuthite, bismuth, arsenopyrite, pyrrhotite, and other sulfides. The vein minerals quartz, topaz, beryl, fluorite, feldspar, and mica are characteristic. Mineralization usually occurred in several stages and was accompanied by greisenization; and in later stages by beresitization and silicification of the country rock. In the sulfide stage of mineralization, tetradymite, tellurium, hessite, and alaite, are present together with bismuthite, chalcopyrite, tetrahedrite, and other sulfur salts.

Due to the presence of a sufficient amount of sulfur, the selenium, although entering into the mineralization, does not form its own minerals but enters isomorphically into the sulfide lattice. Bismuth sulfide is characterized by an exceptionally high selenium content (up to 0.02 percent), whereas, in other sulfides selenium is present only in thousandths of a percent. Tellurium content in ore deposits of such types is usually higher than the selenium content, and sometimes reaches tenths of a percent.

Deposits of Belukha and Bukuka in Transbaikal, and Karaoba in Kazakhstan are examples of such deposits. Practical value of these deposits in terms of selenium and tellurium extraction is still not clear because they have never been studied, but undoubtedly they are worth attention due to the noticeable tellurium content.

Cassiterite-Quartz-Sulfide Type Deposits

S.S. Smirnov distinguishes three chief types of tin ores: pegmatitic, quartz-cassiteritic, and sulfide-cassiteritic. The necessity for distinguishing the transitional cassiterite-quartz-sulfide type has been demonstrated by later investigators. According to I.F. Grigoryev and Ye. I. Dolomanova [1], deposits of this type are associated with the intrusive granophyre, biotite granite, or granodiorite porphyry of small dimension (chiefly of Mesozoic age), which are stock-shaped or dike-shaped bodies. Containing rocks are in a majority of cases sandstone or shale, metamorphosed at the contacts with these intrusives.

Ore bodies of this type include lodes, stockworks, zones of brecciation, fractured veins and lenses. A multistage process of mineralization is characteristic of these deposits; the paragenetic association of minerals of separate stages indicates considerable changes in the ore solution with time. Typical minerals of deposits of this type are arsenopyrite, pyrrhotite, sphalerite, galena, chalcopyrite, cassiterite, wolframite, scheelite, stannite, pyrite, molybdenite, tetrahedrite, telluride, bismuth, gold and silver, bismuth and lead selenide, bismuthite, cosalite, hematite, gold, pyrargerite, argentite, prusstite, auripigment, and boulangerite. Nonmetallic minerals are represented by tourmaline, chlorite, muscovite, quartz, topaz, fluorite, adularia, axinite, and pyrophyllite. Separation of selenium and tellurium into their own minerals (tetradymite, joseite, calaverite, altaite, guanajuatite, platinite, and others) were deposited during one of the latest stages of mineralization characterized by deposition of sulfur salts of lead, bismuth, and silver. Deposits of Nevskoye, Ignodinskoye, Sokhondo, Zun-Undur, and others are of this type.

The industrial value of such deposits (transitional type) probably is very small, because the minerals of tellurium and selenium occur very rarely, chiefly in upper levels of deposits, and sulfides containing them as isomorphic admixtures usually are not utilized.

Selenium evidently does not occur with the lead deposits of other types; tellurium is present only to a very small degree.

Chalcopyrite-Molybdenite Type Deposits

Close volumetric and genetic relationships to moderately acid granitoids are characteristic of this type. In a majority of cases, the deposit is related to large multiphase intrusives situated in exo-contacts of the youngest acid phases of granite-granodiorite content or inside the small stocks of acid granitoids. Mineralization is usually related to regional faults and is related to fracturing. Mineralization occurs over a considerable area (up to

several kilometers) and includes stockwork ore bodies and a zone of impregnation. Relatively large quartz-ore veins along the strike and at a depth of hundreds of meters are of less importance. Only separate sections of veins are pay-zones.

Chief ore minerals of deposits of this type are: pyrite, chalcopyrite, and molybdenite. Less abundant are: hematite, magnetite, bornite, sphalerite, galena, enargite, bismuthite, arsenopyrite, argentite, tennantite, and native gold. The main vein minerals are quartz and carbonates. Mineralization is accompanied by sericitization and chloritization of the host rocks. Several stages of copper-molybdenum mineralization are distinctly separated. Large and very large deposits occur among the copper-molybdenum deposits.

Until recently, data on the presence and distribution of selenium and tellurium in the deposits of this type has not been available. Only the presence of an insignificant quantity of such minerals has been indicated in the ores of Paragachaysk copper-molybdenum deposits (eucairite, umangite, petzite, altaite; the accuracy of selenide diagnostics is doubtful). At the present time both elements are found in the ores of several deposits of the Caucasus together with molybdenite, chalcopyrite, and pyrite. Selenium content in molybdenite of several deposits reached 0.003 percent, chalcopyrite 0.01 percent, and pyrite 0.0063 percent.

Tellurium content in molybdenite is from 0.0053 to 0.0008 percent, in chalcopyrite -- from 0.0031 to 0.0009 percent. The highest percentage of this element is found in pyrite (up to 0.0072 percent). Sphalerite has not shown either selenium or tellurium (within the limits of accuracy of this analysis). The following regularity was noted: the minerals of early stages of mineralization contain less selenium or tellurium than later minerals.

Kadzharan, Dastakert, Agarak, and other deposits are of this type in the Soviet Union. There are no data on the presence of selenium or tellurium in similar foreign deposits.

Pyrite Type Deposits

The ores of the pyrite type are usually connected with volcanic-sedimentary strata, where they form the lenses, and bodies of regular form of massive pyrite-chalcopyrite ores. Genetically, the pyrite ores are thought, by some investigators, to be related to subvolcanic intrusives and the root part of extrusive masses in which the pyrite deposits are situated; other investigators associate them with acid granite intrusives. The following minerals occur in the deep-seated ores: pyrite, chalcopyrite, sphalerite, more rarely tetrahydrite, galena, bornite, pyrrhotite, orange bornite, renierite, and others. Alteration of contact rocks is characterized by sericitization and chloritization.

Selenium and tellurium are typical associates of all pyrite ores, the main source of these elements. Selenium content is usually thousandths, seldom hundredths of a percent, tellurium content -- thousandths and ten-thousandths of a percent. In chalcopyrite and pure pyrite a greater concentration of selenium is common. Varieties of pyrite occur with sphalerite and are characterized, as a rule, by a lower selenium and tellurium content; they have no more than thousandths of a percent selenium and, ten-thousandths of a percent tellurium; but in pyrite and chalcopyrite the selenium content sometimes reaches 0.1 percent and tellurium 0.01 percent. The ratio between selenium and tellurium generally is 3:1 or 4:1, but in some deposits of Southern Ural it reaches 1:1 and even 1:1.5.

In all pyritic deposits, selenium is present exclusively as an isomorphic admixture in the sulfide lattice. Tellurium forms its own minerals; altaite, tetradymite, calaverite, and hessite. The dimensions of telluride segregations are hundredths and thousandths of a millimeter. Tellurides evidently are more characteristic of impregnated type ores but are also found in massive pyrite ores.

The conception of tellurium occurring as an isomorphic admixture in the sulfide lattice originated in the "premicroscopic" period of ore study, and now needs revision. In all cases where the tellurium content of the ore reaches hundredths of a percent, its own minerals are found. This may indicate the presence of tellurides in a submicroscopic state.

Typical representatives of this type of occurrence are the pyrite deposits of Ural (Degtyarka, Karpushikha, Blyava, Sibay, Uchaly, etc.), deposits of Rio Tinto in southern Spain, pyrite deposits of Japan, and elsewhere. The potential reserves of selenium and tellurium in the deposits of pyrite are considerable.

Cobaltite-Selenide-Telluride Type Deposits

The specific complex of minerals and the wide distribution in northeast U.S.S.R. requires separation of this type of ore as an independent unit. The deposits of this type are genetically associated with the differen-

tiation of moderately acid granite intrusives.

The mineralized rocks are chiefly metamorphic sedimentary rocks predominantly of Mesozoic age (Triassic, Jurassic).

Mineralization occurred along small dislocations, fracture zones, and areas of crushing and contortion. Secondary dislocation along contacts with vein rocks was commonly observed:

In this type of deposit the most widely distributed mineral is cobaltite; widely distributed are: less scutterudite, schmaltite, arsenopyrite, pyrite, phrrhotite, cholantite, gersdorffite, glaucodot, native bismuth, chalcopyrite, galena, petrodimite, hessite, krennerite, clausthalite, guanajuatite, breithauptite, millerite, prusstite, and pyrargirite. Vein materials are quartz, chlorite, tourmaline, adularia, sanidine, calcite, and axinite. Several stages of mineralization are distinguishable; selenides and tellurides have been deposited simultaneously with sulfoarsenides of cobalt. Deposition of sulfides occurred later in a separate stage of mineralization. Selenium content in ores fluctuates from 0.002-0.0001 percent and, tellurium content 0.0007-0.0002 percent.

The largest deposit of this type is Verkhne-Seymchansk. Industrial importance of deposits of this genetic type could be very great.

Selenide Type Deposits

Deposits in which the selenium minerals are the only, or the chief minerals, are relatively rare. About 1823, near Tilkerode, Lehrbach, and Sorge in Harz, Germany, poor siderite-hematite veins were found, filling fissures in diabase ore minerals. Minerals present included clausthalite, eucairite, umangite, timmanite, and local naumannite, and berzelianite. The first known selenides were described from these minerals, but they had no industrial value and therefore were not thoroughly studied. A vein of analogous character is known in San Andreasberg, Germany. In 1871, Klokman described a calcite vein in limestone which contained clausthalite, naumannite, klokmannite, umangite, and eucairite from Sierra de Cacheuta and Sierra de Umango in Argentine. In 1910, Wittich described quartz veins with tourmaline, fluorite, and barite from Guanajuato in Mexico in which, besides the bismuth, iron selenide and molybdenite were present; this, evidently, testifies to a very high temperature of formation, higher than for the majority of analogous cases. In the quarry of Trogtal near the village of Lautenthal, Germany, thin dolomitic veins in greywackes with thin-scaled hematite, clausthalite, and cobalt and lead selenide are present.

The largest true selenium deposit known at present is Pacajaca in Bolivia; it is deposited between Devonian shales near the axis of the Pacajaca anticline. Selenium mineralization is connected here with a barite-siderite vein and forms a kind of "ore pillar." Data on geology of the deposit is very poor. The main ore mineral is blockite.

Uraninite-Selinide Type Deposits

Selenium, and commonly tellurium, are constantly present in a majority of high and low temperature hydrothermal uranium deposits, genetically related to acid and moderately acid granitoid rocks. Due to the absence of sulfur these two elements, as a rule, are not in the form of an isomorphic admixture but occur as distinct minerals. Selenides are known in high temperature hydrothermal deposits of pitchblende associated with magnetite, hematite, and sometimes with small quantities of cobalt and nickel arsenides (Schmideberg deposit in Silesia).

Medium and high temperature ores in hydrothermal copper-uranium-cobalt deposits (Katanga region in Belgian Congo) contain selenides and tellurides [12] associated with uraninite, molybdenite, linnaeite, covellite, waesite, and other minerals.

Selenides and tellurides in high-temperature hydrothermal uranium deposits containing eight metallic elements in the Athabaska region in Canada are known. Associated with pitchblende and native copper are a whole series of copper, lead, and mercury selenides. Moderate-temperature uranium deposits containing five metallic elements judging from certain Saxonian deposits [9], also contain selenium in their ores associated with arsenides of nickel and cobalt, bismuthite, native bismuth, argentite, native silver, chalcopyrite, hematite, carbonates, and quartz. Unfortunately, there are no data on the form of selenium in these deposits. Very likely it occurs with bismuth and possibly with certain silver minerals.

Gold Ores

The number of native compounds of gold is very limited. Besides native gold, there are only rare compounds of gold with bismuth (maldonite), with silver (electrum), and

with palladium (porpezite). Tellurium is the only element forming a series of minerals with gold; therefore, it is one of the constant associates of gold in its deposits. It is most widely distributed in low-temperature hydrothermal deposits where gold and silver telluride ores occur. Selenium is rarely found in gold deposits; generally it combines only with silver, or enters isomorphically into the lattices of sulfide minerals.

Hypothermal gold deposits are divided into the following types: 1) gold-arsenopyrite-tourmaline; 2) quartz-gold; 3) gold-silver-quartz-adularia; 4) gold-selenium (tentatively identified by Schneiderhoh, 1955).

1) Gold-arsenopyrite-tourmaline type deposits are usually situated between Precambrian and Paleozoic granitoid massif and metamorphic rocks. More commonly they are represented by gold-bearing quartz veins, more rarely as silicified and pyritized schists. The following minerals are found in the ore: arsenopyrite, pyrite, phrrhotite, chalcopyrite, sphalerite, tetrahedrite, gold, and occasionally molybdenite. Nonmetallic minerals are represented by quartz, tourmaline, and actinolite.

Tellurium in deposits of this type usually occurs in the form of bismuth telluride (tetradymite). Its distribution in ore bodies is very regular; an enriched section with small but macroscopic crystals of tetradymite is present. Selenium never forms its own minerals, and its content in ores is usually very low ($1X10^{-3}$--$1X10^{-4}$). Kochkar' in South Ural, Sovetskiy Rudnik in the Yenisey Mountain Range, and Kommunar in Mariinskaya Taiga, are examples of this type of deposit.

2) Quartz-gold-ore type. Deposits of this type occur in Mesozoic, Cenozoic or Paleozoic granitoids. They are usually represented by regular, well-formed veins. Ore and gangue consist of quartz, carbonate, barite, pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, and native gold.

Tellurium is almost always present in deposits of this type, forming calaverite, altaite, hessite, tetradymite, and other minerals. Telluride segregations usually are microscopic. Only tetradymite is found in the form of microscopic crystals. Its accumulation in ore bodies is inconstant, in places reaching 0.5 percent.

In such deposits selenium usually does not form its own mineral. It is contained only in sulfides, the quantity of which in this type of deposit is very considerable. Its concentration in these minerals, especially in pyrite, is within a thousandth of a percent.

Berezovskaya, Stepnyak, Dzhelambet, Stalinskoye, Tsentral'noye, Berikul', Saralinskoye, Darasun, and others are examples of such deposits in the territory of the U.S.S.R.

3) Gold-silver-quartz-adularia type. Low-temperature, gold-bearing deposits are usually genetically related to Tertiary volcanic activity and are represented by veins and stockwork zones formed at shallow depth. They are associated chiefly with extrusions of andesite and dacite, and may also be related to active hot springs. The mineralization is irregular, pocket-like in form.

Quartz is represented by low-temperature varieties. Besides, calcite, rhodochrosite, barite, and adularia are present. Native gold present contains silver. Gold and silver tellurides, sulfides, and silver, lead, and bismuth selenides are widely distributed.

Tellurium is broadly represented in deposits of such types, and in certain cases could be of industrial value.

Selenium is also very commonly found; it forms microscopic segregations of silver selenides. Selenium content is so high in places that nuggets of gold contain up to 3.86 percent of selenium (Sumatra).

Deposits of this type are widely developed in the Pacific Ocean belt and in the Balkans. Redjanglebong, Simpang, and Sulit on Sumatra, Comstock and Goldfield in the U.S.A., El Oro in Mexico, several deposits in Chile, Peru, the Philippine Islands, and Japan are examples of such deposits. Deposits in Nagiak Transylvania are well known. In the territory of the U.S.S.R., this type of deposit is probably represented by Baley, but unfortunately, it still has not been sufficiently studied in respect to selenium and tellurium.

In terms of their chief component, i.e., gold, these are large-scale deposits. In certain cases (Nagiak), they could also be important and even very important in regard to selenium and tellurium, although they are still not industrial sources of these elements.

4) Gold-selenium type. Because of its exceptional character, this deposit was tentatively distinguished as a separate type by Schneiderhohn. The only known deposit is Eisenberg near Korbach, Germany. At present it is still not industrially important, although in the middle ages it was a big enterprise.

Mineralization of this deposit is almost totally in alum shales of Culm age. It is usually found in deformations caused by

shearing, zones of crushing, and normal and reverse faults. The fractures are filled with calcite, native gold and clausthalite. Regardless of content, the rocks not subjected to tectonic forces do not contain gold even a few millimeters from the small calcite veins.

Therefore, the recognition of this deposit as an independent genetic type we consider unjustified.

Galena-Sphalerite Type Deposits

This group of moderate-temperature, lead-zinc deposits is the most numerous and important source of industrial selenium and tellurium.

It could be divided into three sub-types according to morphology of ore bodies and their condition of deposition:

1. Vein deposits in gneiss, granite, massive extrusive rocks, schist, etc.

2. Lenses in volcanic sedimentary rocks (e.g., polymetallic deposits of Altay).

3. Pipe-shaped and other complex ore bodies in carbonate rocks (e.g., the majority of Nerchinsk deposits).

These deposits are genetically related to granitoids, although in many cases the source of mineralization remains unknown. The majority of these deposits are Varissian, Kimmerian, and Alpian in age, but Proterozoic deposits are also known.

Ore minerals here are: galena, sphalerite, pyrite, tetrahedrite, and chalcopyrite. There is also silver, native gold, and sometimes uranium and thorium in small amounts. Vein minerals are quartz, barite, carbonates, sericite, and chlorite.

Ores of all three sub-types contain admixtures of selenium and tellurium, but in ores of the first and second sub-types the content of these elements is hardly up to the Clarke index of concentration. Quantity of tellurium is slightly higher than that of selenium. The microscopic segregation of minerals of tellurium, chiefly altaite and more rarely hessite, is not common.

In the ores of the second sub-type, the content of selenium and tellurium in places reaches 20 to 200 gms per ton. Tellurium, as a rule, is well-expressed mineralogically and forms a series of tellurides: altaite, hessite, and calaverite. Tellurides have microscopic dimensions and are usually closely associated with galena. It is characteristic that lead telluride, altaite, is found together with galena. In extremely rare individual cases, the tellurides form nest-like accumulations weighing several hundred kilograms (Zavodinsk deposit in Altay).

Selenium is never expressed mineralogically although its content reaches 200 gms per ton, and it usually occurs isomorphically in the lattices of galena, sphalerite, and pyrite.

Polymetallic deposits of Altay (Zavodinsk, Zyryanovsk, Lazursk, and others) are the most typical representatives of this sub-type. Reserves of selenium and tellurium are considerable.

Cinnabar-Antimonite Type Deposits

All industrial deposits of mercury are low-temperature hydrothermal deposits, whose genetic relation with intrusive and volcanic sources is not commonly clear.

The matrix rocks are moderately acid granitoids and their alkalic derivatives. Stratified deposits in sandstone or quartzite control the prevailing form of the ore bodies. By mineral association they can be classified into: 1) cinnabaric; 2) cinnabaric-antimonitic; 3) mercury-polymetallic; 4) gold-mercury with gold telluride; and 5) mercury-arsenic, where cinnabar is associated with auripigment and realgar.

These deposits are divided into two types according to the geologic condition of formation. The first type was formed at medium depth and is related to moderately acid granitoids not exposed at the surface. To this group belong the world's greatest deposit of Almaden, Idria, and some deposits of the Soviet Union and China. The second type formed at shallow depth in connection with volcanic activity and hot springs. Their age is Quaternary or Recent. They are characterized by the complex mineralogic composition, colloform texture, and cryptocrystalline character of cinnabar, which distinguishes them from the first type. To this type belongs one of the largest deposits in the world, Monte-Amiata in Italy, and also several deposits in the U.S.A., New Zealand, Mexico, Chile, Peru, Japan, and the Caucasus.

Prospecting for selenium and tellurium in the mercury deposits has not been seriously considered by anyone and our knowledge in this respect is very limited, although Schneiderhohn discusses them and recognizes even the mercury-antimony-selenium type deposit. Mercury ore bodies are genetically probably favorable for selenium concentrations.

In some mercury deposits, timmanite (mercury selenide) forms an isomorphic series with metacinnabar. The members of this isomorphic series are known in mineralogy as onofrite. In the mercury deposit of San Onofrio, Mexico, ores occur with the ratio S: S:Se= 1:3.9. Selenides are found in the ores of San Louis, Potosi-Guerrero in Mexico, in the provinces of Kwei-Chow, Unan, and Hunan in China. Data on isomorphic association of selenium in the cinnabar lattice are absent.

EXOGENIC DEPOSITS

Carnotite-Black Type

By genesis, carnotite-black ores are divided into two groups, which do not everywhere differ greatly.

1) So-called "carnotite" ores are well-represented in the Colorado plateau in the U.S.A. The use of the term "carnotite" for these ores has been arbitrary, because there are many ores of other types in their mineralization. A series of contradictory hypotheses exist regarding their genesis, but all of them sound well justified. Some investigators consider these ores infiltration deposits originating as a result of precipitation of sulfate compounds of uranium and vanadium and carbonates together with organic matter from ground water; other investigators consider them hydrothermal deposits related to deep-seated sources.

2) Sedimentary uranium deposits of black bituminous and coal shale, and the uranium-bearing phosphorites are also related to marine lagoonal and partly deltaic lacustrine and fluvial sedimentary deposits.

Selenium is present in ores of both types. It was first recognized that selenium is present in the form of crystals of native selenium [11] two millimeters long, associated with carnotite, roscoelite, and gypsum. Its quantity is in places very high (up to tenths of a percent). Later, the presence of ferroselite, clausthalite, eucairite [6] was recognized. Selenide formation in the deposits of exogenic character, evidently, is analogous to the formation of pyrite in reducing conditions. Selenium content in ores is usually in hundredths and thousandths of a percent, but sometimes reaches tenths of a percent. Data on the presence of tellurium is lacking.

Residual Deposits of the Iron Cap Type

Of residual deposits, only the type due to erosion of sulfide deposits is of interest in this connection. The presence of a small amount of selenium and tellurium in an iron cap could be a good prospecting lead for sulfide deposits [3] because it is not always easy to determine to which type of primary ores the iron caps are related.

During oxidation and dissolution of sulfide deposits by surface waters, some elements are carried out of the zone of oxidation; others form insoluble or almost insoluble compounds and because of that remain in situ, and the last are carried away from the decomposed country rock.

Selenium and tellurium enter into solution during the erosion of sulfide deposits in the oxidation stage; this is evident from their presence in mine water. However, being subject to reduction, they are precipitated from solution chiefly in the form of native metals or ferrous compounds. Therefore, the oxidation zone of sulfide deposits contains two elements about in the same quantity as primary sulfide ores.

Certain enrichments, particularly of selenium, take place in zones of leaching where it is accumulated with sulfate. The jarosite and native sulfur forming on the border of zones of leaching are especially rich in selenium. The jarosites of Maykain, and many pyrite deposits of South Ural (Khul'-Urt-Tau, Uchaly, Buribay, Blyava) could be considered as examples of such enriched zones. A considerable selenium content was noticed by P.P. Pilipenko in jarosites of the oxidation zone in certain deposits in Altay (Nikolayevsk, Chudak, Talovsk). Selenium content in the oxidation zone is from $1 \cdot 10^{-3}$ to $1 \cdot 10^{-4}$ percent. Tellurium content is one order lower. In the leaching zone, the selenium content is sometimes increased up to one percent in certain deposits (Khul'-Urt-Tau, Buribay), but the average is $1 \cdot 10^{-1}$ to $1 \cdot 10^{-2}$ percent. Tellurium does not usually occur in exceptionally high concentrations.

Deposits of this type can become the industrial sources of selenium.

Gold Telluride Placer Deposits

Some placer deposits are of interest with respect to tellurium, but selenium has not been found in the deposits of this type.

It is known that tellurium forms minerals with a series of heavy metals: gold, silver, and bismuth, which are found in very considerable accumulations. All these minerals are very stable, resistant to erosion, and

have a high specific gravity; this is the reason that they have been concentrated in placer deposits together with native gold. However, due to their softness, they are quickly rounded off and eroded, therefore, they occur in close proximity to the main deposits. Such small placer deposits containing tellurides are known in the Pribaikal area, Eastern Transbaikal, and Primorye (deposits of Upper Angara, Khorogocha Valley, Malaya Chirka) in the U. S. S. R.

Deposits of this type have not yet become objects of mining for tellurium because the small demand for this element has been fully covered by the extraction of tellurium as a by-product from copper (electrolytic process), but some deposits of this type can contain very large reserves of tellurium.

Conclusions

1. One of the main geochemical properties of selenium and tellurium is their ambivalent character which brings both elements to the border between normal and trace elements. Because of this ambivalence a considerable quantity of selenium is dispersed in deposits of its chemical analogue, sulfur, because it is close in chemical properties. In other cases, selenium, particularly tellurium, due to the differences between their properties and those of sulfur, become fixed in the form of independent minerals under certain conditions; in this way considerable accumulations are formed.

2. Because the extraction of elenium and tellurium as by-products from copper and pyrite deposits has satisfied the needs of industry up to now, the study of different genetic-type deposits practically has not been carried out. The first attempt to classify genetic types of deposits containing selenium and tellurium and to give their geologic characteristics and industrial evaluation has been done in this work.

3. These deposits can be formed by different endogenic processes as shown in this study. The largest reserves of selenium are related to certain magmatic deposits. The largest reserves of tellurium together with selenium are associated with postmagmatic deposits containing pyrite and copper-bearing molybdenum. Besides, several other postmagmatic ore bodies also have tellurium and selenium, and potentially can be the source of these elements. Here we must mention the series of lead-zinc, cassiterite-quartz-sulfide, cobaltite-selenide-telluride, arsenopyrite, gold ore and other deposits. The formation of selenium deposits in association with uranium is related to exogenic processes. Industrial deposits of tellurium of analogous character are not known. We know only small-scale deposits of tellurides of classtic origin.

4. In sulfide deposits, the highest selenium content is usually held by chalcopyrite and the lowest by sphalerite, but together with chalcopyrite a similar and sometimes high content characterizes pyrite and molybdenite. The latest stages in the process of mineralization developed the highest concentration. Tellurium also has a higher concentration in the same minerals and in the same stages. In lead-zinc deposits tellurium is concentrated chiefly in galena.

5. The largest number of selenium- and tellurium-bearing deposits are related to acid or moderately acid granitoids but the largest reserves of this element occur chiefly in basic intrusives. Deposits related to alkalic rocks are of minor importance.

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STRATIGRAPHY OF THE MIDDLE PALEOZOIC EXTRUSIVE SERIES OF THE SOUTHWESTERN SPURS OF NORTH TIEN SHAN

by

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ABSTRACT

Stratigraphic problems of Middle and Upper Paleozoic extrusive rocks of the southwestern slopes of northern Tien Shan are considered in this article. The authors criticize the generally accepted scheme of N.P. Vasil'kovskiy and offer several considerable changes and refinement of his classification.

* * * * *

The vast region of the southwestern slopes of northern Tien Shan is characterized by an extensive volcanic formation of Middle and chiefly Late Paleozoic Age. Due to the difficulties connected with the stratigraphic classification of extrusive rocks, the stratigraphy of these deposits remained incomplete for a long time. Early stratigraphic schemes of Ye. V. Ivanov, S.F. Mashkovtsev, B.N. Nasledov, A.P. Nedzvetskiy, A.S. Adelung, Ye. D. Karpova, P.N. Sokolov, and others, dealt only with separate, unrelated areas, which could not be correlated.

The first stratigraphic scheme of this region as a whole was completed by a small group of Central Asian geologists with the direct participation and under the direction of N.P. Vasil'kovskiy. This work of almost ten years was completed in 1947 by the preparation of a general stratigraphic scheme of Upper Paleozoic deposits of the southwestern slopes of North Tien Shan. It later underwent certain changes and was published in its final form by N.P. Vasil'kovskiy in 1952. The publication of this work was a great help in understanding the stratigraphy and volcanism of the Upper Paleozoic of the southwestern slopes of North Tien Shan. N.P. Vasil'kovskiy's work has been universally accepted, and up to the present has been the handbook of every Central Asian geologist.

The final review and publication of the stratigraphic scheme of N.P. Vasil'kovskiy coincided with the beginning of study of the southwestern slopes of North Tien Shan, including tectonics and volcanism of Upper Paleozoic deposits, by the Institute of Geological Science of the U.S.S.R. Academy of Sciences. However, during this study, new data was collected which was contradictory to certain conceptions of the existing scheme.

The number of these contradictions increased from year to year and forced us to review several of the stratigraphic columns of N.P. Vasil'kovskiy; this article is devoted to this review.

Omitting a description of the Lower and Middle Devonian extrusives, whose stratigraphic position and existence has never been disputed, we will concentrate on the stratigraphy of the extrusive formations deposited in Middle and Late Paleozoic time. A series of works of N.P. Vasil'kovskiy and other investigators has been devoted to these deposits.

The stratigraphic scheme of the Upper Paleozoic, according to N.P. Vasil'kovskiy, begins with a sequence of sedimentary and extrusive rocks lying unconformably on limestones of the Upper Wise.

In his last monumental work, N.P. Vasil'kovskiy [4] gives this scheme in the following form (from bottom to top):

Lower Carboniferous

1. Arkutsay extrusive formation; thickness up to 200 meters (Upper Wise).

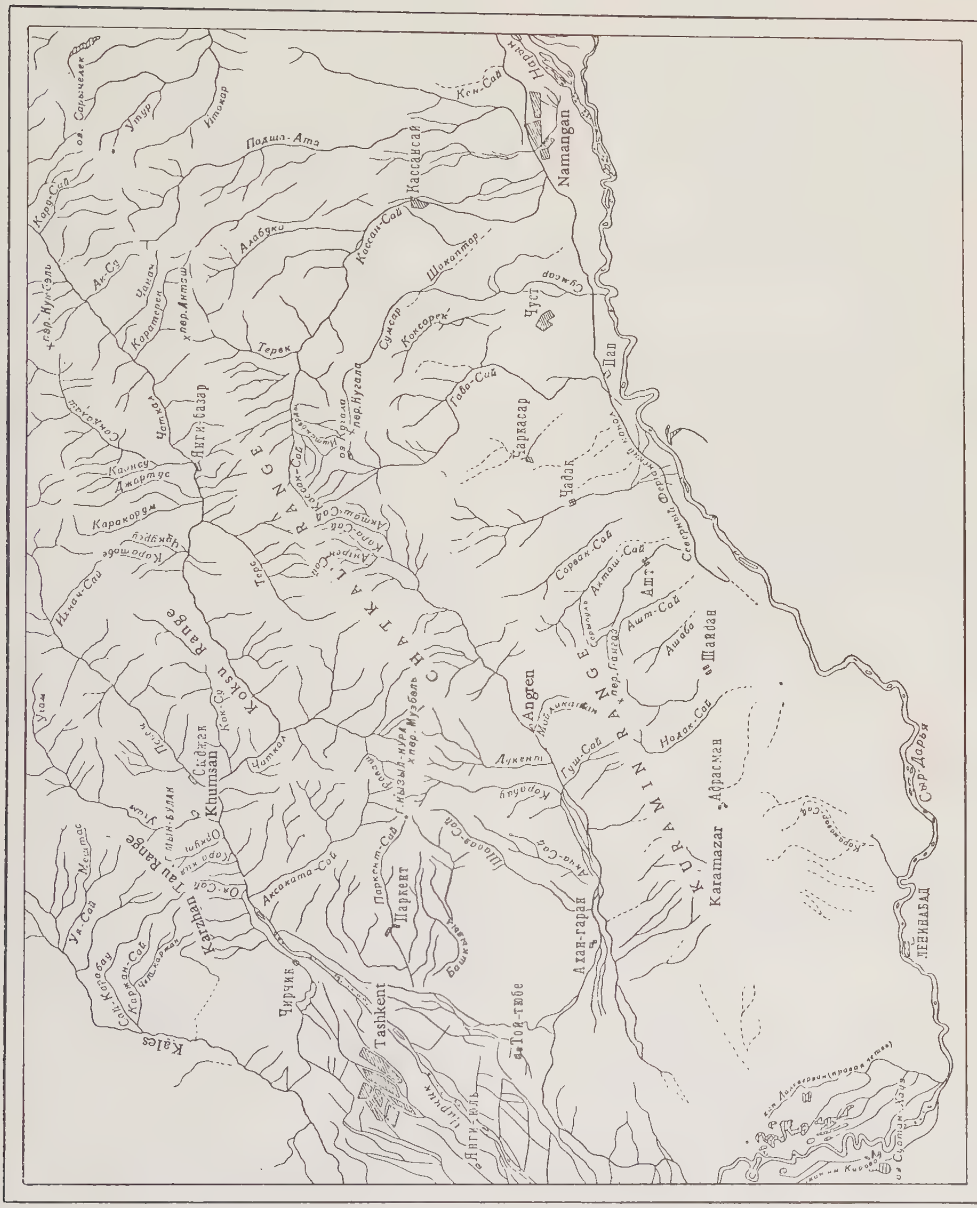

Fig. 1. Geographic Scheme of the Upper Slopes of Southwestern Tien Shan

2. Kyzylsu extrusive formation; thickness about 1,150 meters (believed to be the Namur formation).

3. Extrusive and sedimentary formation Uya; thickness up to 1,000 meters (Namur formation).

Middle Carboniferous

4. Mynbulak extrusive formation; thickness more than 3,600 meters.

Upper Carboniferous

5. Akchinsk extrusive formation; thickness up to 2,500 meters.

6. Sarysiyun sedimentary extrusive formation; thickness up to 500 meters.

7. Oyasay extrusive formation; thickness up to 2,500 meters.

8. Karzhansay sedimentary extrusive formation; thickness about 140 meters.

The last four formations are grouped in the Aktash volcanic complex.

Lower Permian

9. Shurabsay sedimentary extrusive formation; thickness about 1,500 meters.

Surmised Upper Permian

10. Ravash sedimentary extrusive formation; thickness about 1,200 meters.

Surmised Lower Triassic

11. Kyzylnurin extrusive formation; thickness about 1,000 meters. The last three formations are grouped in the Aksakatin extrusive complex.

In this scheme, our attention should be drawn to the fact that the two lower formations -- Arkutsay and Kyzylsu -- and also the Karzhansay formation were described by N.P. Vasil'kovskiy as local formations which are not extensively distributed even in the Karzhan-Tau Mountain Range, where they were first recognized.

When we were about ready to send our manuscript to be printed, one more article of N.P. Vasil'kovskiy [5] on the stratigraphy of the Upper Paleozoic volcanic formation of the southwestern slopes of North Tien Shan was published. In this article N.P. Vasil'kovskiy keeps his original scheme of the age sequence and the number of sedimentary volcanic formations, but reduced here to nine on account of the absence of the Kyzylsu and Karzhansay formations. In this article the geologic ages of several formations were revised and the unconformity and folding between the Akchinsk and Sarysiyun formations is noted. Basically, the article contains a series of new assumptions on different stratigraphic problems of this region but reliable factual materials, permitting solution of the concepts assumed by the author, are lacking. Below, during the description of the formations, we note and consider the most important assumptions of N.P. Vasil'kovskiy as expressed in his last article [5].

Arkutsay Formation

N.P. Vasil'kovskiy considers as part of the Arkutsay formation the porphyrites on the right side of the Ugam River west and northwest of the village of Khumsan. According to position we can recognize extrusive and intrusive porphyrites, of which the first are classified as the Arkutsay formation and the second are considered intrusive analogues. According to his data the porphyrites cut Wise limestones; their pebbles are abundant in the conglomerate of the Uya formation. From this, the age of the Arkutsay porphyrite is determined as Upper Wise. A.B. Kazhdan, while studying this region in 1954, determined that the area of distribution of the Arkutsay porphyrite is limited by the small surface area of the basin of the Arkutsay River and the narrow strip trending northwest in the valley of the middle Karakoz River (right tributary of the Ugam River). Intrusive analogues of porphyrites, cutting Lower Carboniferous limestone, are found only in the basin of the Arkutsay River. Farther north, among the extrusive varieties of porphyrite, the interlayer of, first pyroclastic, and then sedimentary materials appears. Fifteen kilometers north of the upper segment of the Arkutsay River, in the valley of Kyzyl-Bulak (left bank of the Uya River), these rocks lie conformably on the Wise limestone and are represented by coarse tuffaceous sandstone, tuff, and tuffaceous conglomerate with very thin interlayers of effusive porphyrite. In the sheets of tuffaceous conglomerate, porphyrites predominate, but a considerable quantity of limestone fragments is also present.

Spirifer bisulcatus Sow., Choristites ex bisulcatiformis Semich. and a goniatite fauna characteristic of the Namur formation and underlying the limestone permits correlation of this limestone with the top of the Wise formation and with the bottom of Namur formation of Early Carboniferous age [4]. A few kilometers below estuary of the Kyzyl-Bulak River, on the Uya River, this section of extrusive and sedimentary rocks is described by N.P. Vasil'kovskiy as the lower part of the Uya formation; according to him "the base of the formation is usually cut by faults, therefore, its contact with the Wise limestone is not visible" (p. 36). However, A.B. Kazhdan has recognized in the Kyzyl-Bulak gorge a distinct, conformable succession of tuffaceous conglomerate of this formation above the limestone of Wise-Lower Namur Age. Therefore, there are several reasons for believing that the so-called Arkutsay porphyrites are facies of the lower part of the Uya formation, and that it is not an independent stratigraphic unit. In regard to other outcrops which N.P. Vasil'kovskiy considered Arkutsay porphyrite, it has been proven by detailed study in the Karzhan-Tau Mountain Range that part of these exposures are the Shurabay formation and part the Akchinsk.

KYZYLSU FORMATION

The Kyzylsuy extrusive and sedimentary formation was recognized by N.P. Vasil'kovskiy in 1938 on the southern slope of the Karzhan-Tau Mountain. This formation is developed on the left side of the valley of the Kyzyl-Su River and is represented by felsite-porphyry, felsite, albitophyre, tuff, tuffaceous sandstone, and tuffaceous lava of acid rocks; it was believed to be 1,150 meters thick. According to Vasil'kovskiy [3], the Kyzylsu formation "changes in the direction of dip, loses Arkutsay porphyrites, and is separated from them by fractures and magmatic dikes." Then the author challenges the conformity of the Kyzylsu formation and the Arkutsay porphyrites and allows the Kyzylsu formation an intermediate position between the Arkutsay and Uya formations.

Later he indicates: "It is possible, however, that the Uya formation changes in direction of strike into the effusive Kyzylsu formation; the reason for this assumption is the presence in the Kyzylsu formation of thick tuffaceous sandstones similar to Uya sandstone. Further, it is possible to consider an even younger age for the Kyzylsu formation compared with the Uya formation. But in this case the formations of the Kyzylsu Valley should be divided by a fault of many hundred meters, for which we have no evidence. Therefore, the data and supposition given by N.P. Vasil'kovskiy distinctly show the absence of sufficient grounds for correlation or stratigraphic classification of this formation. Admitting inconsistencies in the Kyzylsuy formation, N.P. Vasil'kovskiy nevertheless arbitrarily gives it a Namur Age.

During study of the central part of Karzhan-Tau Mountain and the Oyasay formation in the watershed region of the mountain range, A.B. Kazhdan has found that all beds of this formation (described by N.P. Vasil'kovskiy [3] as the upper Oyasay formation) are distinctly traceable along the strike not only in the basin of Oyasay and Kara-Kiya River and farther southeast to the Kyzylsu and Karakoza-Say Rivers. Full identity of sections of these regions is thus established by these observations.

Therefore, it is now possible to insist that there is no independent Kyzylsu formation and that the rock of the Oyasay formation grouped by N.P. Vasil'kovskiy in the Kyzylsu formation, are the eastern continuation of the Oyasay formation. This is supported by the stratigraphic position in the Karakozy-Say basin where it is underlain by extrusive and sedimentary rocks of the Akchinsk formation (considered earlier as Arkutsay) and is overlain by sedimentary and volcanic rocks of the Myn-Bulak Mountain Region, which N.P. Vasil'kovskiy [3, 4] has taken for the Myn-Bulak formation and which, as will be shown lower, are correlative with the Lower Permian deposits of the Shurabsay formation.

In his last article, N.P. Vasil'kovskiy [5] also admits that the Kyzylsuy formation is not an independent stratigraphic unit. He does not amplify this statement and therefore the stratigraphic position of rock previously correlated with the Kyzylsuy formation have no place in the scheme of N.P. Vasil'kovskiy.

UYA FORMATION AND MYN-BULAK FORMATION

The Lower Carboniferous Age of extrusive and sedimentary rocks was first recognized in 1904 by V.N. Veber [6] for the northwestern part of the Karzhan-Tau Mountains in the basin of the Uya River. He writes (p. 363) "evidently volcanic activity began at the end of deposition of Carboniferous limestones. Volcanic beds partly cut the limestone and are partly interbedded with them." Later, N.P. Vasil'-kovskiy [3] separated these deposits into an independent Uya formation, from which beds abundant fossil fauna was collected, permitting

correlation of this formation with the Namur formation of the Lower Carboniferous. Contrary to V.N. Veber, N.P. Vasil'kovskiy considered that the Uya formation rests unconformably on Lower Carboniferous limestones. According to him, before the deposition of the Uya formation, a tectonic phase had taken place, accompanied by intrusion of magmatic rock. This conclusion was arrived at by N.P. Vasil'kovskiy on the basis of the discovery of pebbles of syenite diorite, monzonite, and quartz diorite in conglomerate in the lower part of the section, meanwhile noticing that no body of such intrusive rocks has been found in Karzhan-Tau Mountain Range and the basin of the Ugam River. Later, N.P. Vasil'kovskiy [4], with certain reservations, correlated with the Uya formation, the sandstone, conglomerate, and limestone of the Bol'shoy Chimgan Region, and correlated the effusive and basalt conglomerate with the layer of limestone of the Sumsar and Koksarek River Basins and sandstone and conglomerate of the Altyntopkan Region.

Simultaneously, N.P. Vasil'kovskiy [4] recognized the so-called Mynbulak formation in the region of Mynbulak Mountain, where, according to him, its full section is exposed. Later he related to the same formation in eastern Karamazar subformation $P^1{}_s$, $P^2{}_s$ and $P^3{}_s$ of A.P. Nedzvetskiy, who carried out in 1945 and 1946 extensive geologic work here. In Chatkal' Mountain Range the Mynbulak formation was correlated with compound variable extrusives occupying considerable areas between the Kumbel' and Kenkol' deformations. In Kuramin Mountain Range this deposit has been noted in southwestern Karamazar.

In the first work of N.P. Vasil'kovskiy there was no information on correlation of the Uya formation and the Mynbulak formation. In his largest work [4], on the basis of revision of data of previous surveys, it is indicated that in the Aktash Mountain Region of Karzhan-Tau Mountain Range, a sharp angular unconformity is present between the Uya formation and the Mynbulak formation overlying it. Local development of Namur extrusives in the basin of the Koksarek River in Chatkal' Mountains, in the basin of the Gava River, and similarity of the Mynbulak formation and Uya formation, as well as absence of reliable data to correlate the separate strata with one or another formation permitted I.P. Kushnarev, in 1953, to express an opinion that the Uya formation and Mynbulak formation are identical.

A.B. Kazhdan, in the southwestern part of Karzhan-Tau Mountain Range, determined that the index section of Mynbulak Mountains should be included not in the Mynbulak formation but in the Shurabsay formation described by N.P. Vasil'kovskiy; this we will discuss later. The same work supported data of V.M. Veber on conformity between the Uya formation and the limestones of the Lower Carboniferous, and it was found that the Mynbulak formation in the region of Karzhan-Tau Mountains is the upper part of the Uya formation. In the north part of this mountain region it lies conformably on the deposits described as the Uya formation and only at the lower course of the Ugam River is a local unconformity present. It is expressed in transgressive deposition of this formation on the Lower Carboniferous limestones.

In 1957, I.P. Kushnarev established an undeniable position for the Shurabsay formation of extrusive and sedimentary rocks of the Ak-Bulak and Kara-Archa River basins (Region of Palatkhan Mountains), which, according to N.P. Vasil'kovskiy, is a type section of the Mynbulak formation in Chatkal' Mountain Range. This section fully coincides with the Shurabsay formation, developed southwest of the Kumbel' dislocation and is very similar to the Mynbulak Mountains section. N.P. Vasil'kovskiy's statement [5] in his monograph [4] that he doubts the relation of the section of the Mynbulak Mountains and the Ak-Bulak basin to the Mynbulak formation is not justified.

The works of A.F. Utkin and I.P. Kushnarev in the Gava-Koksarek River basin have determined that the so-called Koksarek formation, separated by A.S. Makarov, Z.P. Artemov, and others, with abundant fauna of the Namur formation and correlated with the Uya formation, is a single stratum correlative with the Mynbulak formation. In some cases, it has been determined that one of these formations is the continuation of another (Gava River basin) in the Nadak and Pangas Rivers basins. The assignment of the sections to one formation was determined by comparison. It was also established that in the region of Urta-Su (Gava River basin) these deposits lie without angular unconformity on a slightly eroded surface of Wise limestone. In the Koksarek River basin, according to data of A.S. Makarov, Z.P. Artemov and others, this formation lies in angular unconformity on underlying rocks.

Therefore, the given data on the Mynbulak formation in Kuramin Mountain Range permits the conclusion that unconformable deposition of these formations on underlying rocks is not regional. Local unconformity is present only in the peripheral zones of development of the Mynbulak formation.

Two sections of the Uya formation are

described in detail by N.P. Vasil'kovskiy; they are: In the Karzhan-Tau Mountains headwaters of the Uya River (Boguchalpak settlement) and farther north in the headwaters of the Dzhigirgen River. In the Uya River Boguchalpak settlement the section is subdivided into five units (from bottom to top):

1. Greenish grey tuffaceous sandstone with lenses and layers of conglomerate, 480 to 500 m thick. The fauna is found in interlayers and lenses, and according to O.I. Sergun'kova is correlative with the Upper Wise or Lower Namur formation (Productus striotus Fisch., Pr. kokdscharensis Grob., Pr. pugilis Phill. cf. carbonaris Kon., Dielasma hastatum Sow., Martinia triquestra Genim. var pentagona Grob.).

2. Limestone and tuffaceous sandstone with subordinate conglomerate interbedded with limestone and interstrata of andesite and hornblende porphyry, 290 m thick. Here, an abundant fauna was collected, which is correlated by O.I. Sergun'kova and L.S. Librovich with the upper part of Lower Namur (Schizophoria, resupunata Mart. (abundant), Productus striatus Fisch., Pr. latisimus Sow., Pr. concinnus Sow., Pr. pungulus M.W., Pr. kokdscharensis Grob., Pr. ex gr. giganteus Mart., Pr. magna Jan., Marginifera schartimienensis Jan., Chonetes laguesiana Kon., Dielasma hastatum Sow. (very many), Athyris sibtilitata Hall. and many others. From goniatites L.S. Librovich recognized: Stenopronorites cf. ferganensis Raus, S. ferganensis Raus., Fumarphoceras bisulcatus Girty mut. Bisat, Gravenoceras sp., Homoceras sp., Gonioloboceras sp. nov. and numerous other fossils (bryozoa, crinoidea, corals, etc.).

3. Conglomerate, sandstone, interbedded with limestone and rarely with tuffaceous, 107-300 m thick. Pebbles of selenite porphyry are contained in the conglomerate of the lower part of the sequence. The brachiopod fauna has about the same content as in unit two.

4. Sandstone with subordinate limestone; total thickness, several tens of meters. On the basis of the following fauna this unit is correlated with the Upper Namur: Productus corrugatus M. Cay (abundant), Pr. concinnus Sow. and others; Spirifer integricostata Phill., Sp. bisulcatus Sow. and others, and also the following: goniatites -- Antracoceras aff. vanderbeckei Ludv., Gastioceras cf. marianum Vern., G. cancellatum Bisat. and a number of other forms.

5. Dark violet, dense paleotrachyte, and porphyries, with thin interbeds of sandstone, 150 m thick. Unfossiliferous.

Quite different from the given section of the headwater region of the Dzhigirgen River in that the volcanic rocks of the Uya formation disappear and the sequence consists of alternate thin-bedded argillaceous limestone, calcareous sandstone and argillaceous siltstone with a fauna of the Upper Wise and Namur. N.P. Vasil'kovskiy noted that this unit is related by gradual transition to limestone strata of the Upper Wise. Analyzing this section, N.P. Vasil'kovskiy established a scheme of facies changes of Namur deposits from the central part of Karzhan-Tau Mountain Range to the north; A.B. Kazhdan has followed the facies changes of Namur strata to the south.

As shown above, to the south from this section carbonates first disappear and then all sedimentary deposits are replaced by extrusive and pyroclastic rocks -- dacite and porphyrite -- including the so-called Arkutsay-porphyrite.

Above unit 5 in the headwater region of the Uya River, thick strata of sedimentary volcanic rocks are deposited; these beds are described by N.P. Vasil'kovskiy as the Mynbulak formation. According to his data [4] there is a basal conglomerate at the base of the formation extending from the basin of the Uya River to the Ugam River valley cutting the Uya formation and grading into the Wise limestones. During the study of the exposures on the slopes of the Meshtas River valley, A.B. Kazhdan did not find either basal conglomerate or traces of unconformable deposition. To the southeast a gradual decrease in thickness of the underlying sedimentary beds of Namur Age occurs, interbeds of carbonates pinch out and then the clastic rocks pinch out and a large quantity of volcanic material appears. Only in the basin of the lower Ugam River, where large tectonic deformations converge, is it possible to suppose unconformable deposition of rocks of the so-called Mynbulak formation on the underlying sediments; however, due to poor exposure, the correlation of these strata is not clearly established. This does not contradict the commonly observed facts of unconformable deposition of this formation in peripheral zones of its development, to which the given region belongs. Therefore, in the Karzhan-Tau Mountain Range, there are no grounds for the separation of two independent formations.

The Mynbuluk formation in the Karzhan-Tau Mountain Range should, therefore, pass into the Uya formation forming its upper part, as is evident from the above data. The age of the rocks of the lower part of section, on the basis of the fauna, is Namur; and in the upper units, a Middle Carboniferous fauna already begins to appear.

For the upper, predominantly effusive, part of the Uya formation the most probable age is Middle Carboniferous.

I. P. Kushnarev and A. F. Utkin, on the basis of their investigation of the Gava and Koksarek River basin, came to the conclusion that the Uya and Mynbulak formations are actually the same, although they have received different names. Deposits with a Namur fauna are present in this region above the Wise limestones and are represented by the basal conglomerate, tuffaceous conglomerate, and sandstone beds with lenses and interbeds of limestone containing a fauna consisting of Eostaffella prisca Raus., Athyris expansa Plius., Productus giganteus Mart., etc. The thickness of these strata ranges from 50 to 450 meters. These beds are conformably overlain by a block of quartz porphyry mixed with tuff and tuffaceous lava, less commonly with dacite porphyries, andesite porphyrite, and spherolite porphyries whose total thickness is 200-300 meters. This mass is affected by the block of andesite porphyrite, dacite porphyries and pyroclastics occurring with them and having a total thickness of 1,200 to 1,300 meters. Total maximum thickness of the formation reaches 2,000 meters.

These deposits have been described by A. S. Makarov, Z. P. Artemova, M. M. Lebed', and Z. S. Rumyantseva who called them the Koksarek formation and correlated them [4] with the Uya formation as did N. P. Vasil'kovskiy. In the meantime, the adjacent region of extrusives similar to those of the Koksarek formation were included by N. P. Vasil'kovskiy in the Mynbulak formation. However, A. F. Utkin and I. P. Kushnarev had recognized in 1954 that they represent the same single continuous layer. The fact that the Namur Age of the Koksarek formation has been based on faunal discoveries in the lower sedimentary part of the formation is interesting, because the upper part is several times thicker and has not yet been described faunally, but is simply assigned to the same Namur formation. Therefore, a Middle Carboniferous age for the extrusives of these beds is more probable and is not contradicted by data on the Karzhan-Tau Mountain Range and the discovery by A. P. Nedzvetskiy in the Kuramin Mountain Range of coral Meniscophillum sp., which, according to N. N. Yakovlev, has a Middle Carboniferous appearance.

Therefore, the age of the Mynbulak formation (Uya formation) should be considered Middle Carboniferous and only the very bottom (the bottom of the Namur formation) assigned to the Lower Carboniferous. This concept was confirmed during the conference dealing with the volume of the Namur formation and its position in the Carboniferous system. According to the general opinion of all participants in the conference, the top of the Namur formation is definitely Middle Carboniferous.

In the last article of N. P. Vasil'kovskiy [5], data on the stratigraphic position of the Mynbulak formation and the Uya formation are contradictory and conclusions are inconsistent. In a new stratigraphic scheme, he again insists that two formations exist as independent stratigraphic units. However, on page 161, he seems to agree with our opinion that the rocks of Myn-bulak Mountain in the Karzhan-Tau Mountain Range should be correlated with the Shurabsay formation. In all the works of N. P. Vasil'kovskiy, the only section which proves the independent existence of the Mynbulak formation is the Myn-bulak Mountain section; thus, it is evident that such claims at present lack factual data to support them.

The last attempt of N. P. Vasil'kovskiy to substantiate the independence of a separate Mynbulak formation is based on the "greenstone" facies of the rocks. This is also not impressive because this symptom is expressed in equal degree by extrusive rocks of the middle Uya formation, the Akchinsk formation, the Shurabsay formation, and even the Oyasay formation. Usually such alterations represented by chloritization and epidotization of rocks develop close to large deformations and fracture zones.

AKCHINSK FORMATION

The Akchinsk sedimentary and extrusive formation, first recognized by Ye. A. Kochnev, is widely distributed throughout the Kuramin zone. Deposits corresponding in age to the Akchinsk formation are described under numerous local names by different geologists. These deposits were grouped under one general name -- the Akchinsk formation -- by N. P. Vasil'kovskiy. Omitting the study of smaller stratigraphic subdivisions of this formation which were recognized only while preparing a large-scale map of the region, we have to note that the deposition of the Akchinsk formation was preceded by one of the largest Upper Paleozoic orogenic phases. This is supported by the unconformable deposition of the Akchinsk formation on the eroded surface of rocks of various, different ages -- from Upper Silurian schist to Middle Carboniferous granodiorite of the Kuramin type.

Basal conglomerate is present at the base of the Akchinsk formation. However, in some regions extrusive and pyroclastic rocks

were deposited (Bashkyzyl-Say and Parkent-Say) directly on an eroded surface. The thickness of the basal conglomerate is variable: from zero to 200 meters.

On the basis of direct tracing of the Akchinsk formation and on analysis of material collected by I.P. Kushnarev along the Kuramin zone, it is possible to separate three sufficiently distinct regions of occurrence of this deposit. The first region occupies a considerable part of the Kuramin Mountain Region west of the Karamazar-Saya basin and south of the Bashtavak deformation, and the north edge of the Mogol-Tau Mountains. It is characterized by a predominance of acid extrusives: quartz porphyry, felsite, felsite porphyry and tuff, tuffaceous lava, and lava breccia over the dacite porphyry and its pyroclastic equivalents. The rocks of this formation are chiefly greyish-brown, violet-brown, and chocolate in color.

The second region occupies the southwestern part of the Chatkal' Mountain Range southwest of the Kenkol' deformation except for the lower basins of Karabau, Dukent-Say, and Akcha-Say Rivers. In this region, lavas different from the first prevail; they are intermediate rocks consisting of andesite porphyrite with a small quantity of diabase porphyrite dacite porphyry and their pyroclastic equivalent.

The third most extensive region in which at least the acid and intermediate extrusives were ejected occupies an intermediate area between the first two regions. This is the region of the southern slope of Chatkal' Mountain Range, or the northern slope of the Kuramin Mountain Range and the southern slope of the mountain region east of Karamazar-Say. The regions of Kugal Lake and evidently the Karzhan-Tau Mountain Range are part of this area. The thickness of the Akchin formation changes from 300 to 450 m on the southwestern edge of Chatkal' Mountain Range and the Gava region to 1,500 to 1,600 m in the central part of the Kuramin zone (northern slope of Chatkal' Mountain Range and Kugal Lake region).

Therefore, the widespread opinion that the Akchin formation is composed of intermediate extrusives has not been confirmed. Faunally, this formation has not been described.

SARYSIYUN FORMATION

The Sarysiyun formation was first recognized by Ye. A. Kochnev in the southwestern edge of Chatkal' Mountain Range. Corresponding to this formation in the Kuramin zone, extrusive and sedimentary deposits are locally developed. In Chatkal' Mountain Range, they occur chiefly in the Chauli, Shavas, Karabau, and Dukent River basins. They are more widely developed in Kuramin Mountain Range, especially in the northeastern half of the Gush-Say, Lashkerek, Loyak, Pangaz, Nadak, and other river basins. Separate sections of the Sarysiyun formation are different one from another but they all have common characteristics. At the base of the formation there are usually the conglomerate, tuffaceous conglomerate, tuffaceous sandstone and brown and red-brown tuff overlying the eroded surface of the Akchinsk formation with stratigraphic and in certain cases with angular unconformity (Shavas-Say and other regions). Although inconsistent in different sections, interbedded sedimentary and commonly acid extrusive and pyroclastic rocks are present higher in the section. Between these rocks, small lenses and rare layers of limestone, bituminous shale, and sandstone, with remnants of a badly preserved fauna occur.

All investigators consider the Sarysiyun formation as a lagoonal-continental formation. The so-called Nadak conglomerate first found by A.S. Adelung and exposed in the headwater region of Nadak-Say and Lashkerek-Say in the watershed part of Kuramin Mountain Range belong to the same formation, according to I.P. Kushnarev and A.F. Utkin. According to I.P. Kushnarev and A.F. Utkin, the Nadak conglomerate was deposited here on an eroded surface of the Akchinsk formation only and is absolutely similar in content and thickness to the Sarysiyun deposits which are exposed directly southeast and northwest of Iron Fracture. N.P. Vasil'kovskiy [4] is of a different opinion and correlates the Nadak conglomerate with the so-called Ravash formation on the grounds that in this conglomerate, only the pebbles of Shaydan granite and Syenito-diorite have been found (Babayob type). However, despite the thorough search of A.F. Utkin and I.P. Kushnarev for the pebbles of Shaydan granite in the Naydak conglomerate, they have not been found and the pebbles of eroded syenite and diorite cannot be compared with Babayob, because absolutely analogous pebbles are found in conglomerates of older formations beginning with the Lower and Middle Devonian.

In his last article, N.P. Vasil'kovskiy [5] based the supposition that the Nadak conglomerate belongs to the Akchinsk formation on even less reliable data. Such difference in opinion testifies to the fact that N.P. Vasil'kovskiy does not have a sufficiently firm opinion on the stratigraphic position of these strata.

The distribution of the Sarysiyun deposits and the character of changes in thickness and facies permits one to suppose that they were accumulated in basins. Maximum thicknesses in the central part of the syncline reach 400 m, diminishing on the periphery to 100 m and less. However, this does not preclude the idea that Sarysiyun sediments might occupy wider areas and were eroded before deposition of the Oyasay formation.

OYASAY FORMATION

The Oyasay formation was first recognized by N.P. Vasil'kovskiy in the Karzhan-Tau Mountain Range. During further investigation, the very wide distribution of this formation in the Kuramin zone was recognized.

As already noted, A.B. Kazhdan considers that the Kyzylsu formation, identified by N.P. Vasil'kovskiy, in the Karzhan-Tau Mountain Range, does not exist here and these rocks should be correlated with the Oyasay formation. In Kuramin Mountain Range, V.N. Levin and the authors correlate this formation with the Tary-Ekan, Aksay, Sferolytic, Tavak, and Adrasman strata of P.N. Sokolov and Ye.D. Karpova.

In deposition of the Oyasay formation on the Sarysiyun formation and older deposits, distinct angular unconformities were developed in separate regions. For example, on the south slope of Chatkal' Mountain Range, in the basins of the Shavas and Duken Rivers, the angle of unconformity reaches 20 to 25^{o} according to B.L. Rybalov. In other parts of this area (for instance, in the region of the lower segment of the Kyzyl-Say) and on the southern slopes of the Kuramin Mountain Range (Karamazar-Say basin), the Oyasay formation overlies the Sarysiyun formation without noticeable angular unconformity, but in separate places thin traces of erosion are visible between the formations. According to the most recent and reliable data, the Oyasay formation was deposited on the eroded surface of Silurian schists, limestones $D_3 + C_1$, Middle Carboniferous granitoids of the Kuramin type and extrusives of the Akchinsk and Sarysiyun formations. In 1956, B.V. Meshcheryakovskiy first recognized the Oyasay formation on the northern slope of the Kuramin Mountain Range in the Gush-Say and Loyak basin, where basal conglomerate of this formation lies unconformably on Akchinsk rocks.

In many places, the Oyasay section begins with blocks of grey, greenish-grey, or brown-violet and brown tuffaceous sandstone and conglomerate interbedded with each other. Their thickness ranges from 60 m to 200 m (Karzhan-Tau Mountain Range). Usually this block is absent and is replaced in the section by felsite, quartz porphyry, and tuff but tuffaceous lava and lava breccia form the thickest strata. Among these strata locally distributed dacite porphyries and their pyroclastic equivalents are present. The color of the Oyasay formation is very different. However, it is lighter than the other extrusive formations of the Kuramin zone. Prevailing colors are yellowish-grey, ash-grey, white, pink, greyish-violet, more rarely brown and red-brown. During the detailed study of the Oyasay formation on the north slope of the Chatkal' Mountain Range, I.P. Kushnarev found on the south and in the basins of the Shavash and Dukent Rivers the rocks that B.L. Rybalov, V.S. Lomov, and other geologists had discovered: the lilac and dark-brown andesite porphyrite and tuffs, which occupy a different stratigraphic position. In the Bash-Kyzyl-Say and Shavas-Say basins, these rocks form a series of extrusives in the middle of the section, grading into sheets 20 to 150 m thick, overlain by acid extrusives and pyroclastic equivalents of the upper Oyasay formation. About the same position is occupied by andesite porphyrite in the region of Ak-Takhta Pass and Muzbel' Mountain Range. They form a unit about 200 meters thick lying conformably on the block of acid extrusives 650 m thick underlying them and overlain here by a block of basal conglomerate of the younger Shurabsay formation.

In the work of N.P. Vasil'kovskiy [4], porphyrites are mentioned in the description of the Oyasay formation, but in not one of his stratigraphic columns are they noted; no importance was given to them. The porphyrites in the region of Ak-Takhta Pass and Muzbel' Mountain Range were considered part of the Shurabsay and Revazh formations only by their petrographic resemblance to these rocks and without due consideration for their geologic position in the general section of this region. During remapping of this area, I.P. Kushnarev determined that the basal conglomerate of Shurbasay formation was unconformably deposited on porphyrites; and therefore, this porphyrite shou should be part of the Oyasay formation.

Inside the Oyasay formation, numerous local unconformities and breaks in the section are present, which has been explained by the continental deposition of this unit and by extrusive activity of sporadically-active, central-vent and fracture-type volcanoes.

The thickness of the Oyasay formation is great. The strata are 650 to 600 m thick. They have been observed only in the basin of left and right tributaries of the Aksak-Aty

and the Muzbel' Mountain Range. In a majority of places its thickness is not less than 850 to 950 meters and in the region of the upper segment of the Shavas and Ala-Tan'ga it reaches 1,500 m, diminishing to the south to 900 m and increasing to the north, on the side of the watershed part of the ridge, to 2,500 m, according to N.P. Vasil'kovskiy [4].

The age of the lower Oyasay formation is determined by its position on the surmised Upper Carboniferous depositions of the Akchinsk and Sarysiyun formations, its upper border by the overlying basal conglomerate of the Shurabsay formation, containing fauna and flora of the Lower Permian. Therefore, the age of this formation is Upper Carboniferous.

KARZHANSAY FORMATION

N.P. Vasil'kovskiy includes the block of extrusive and sedimentary rocks, exposed for several square kilometers in the basin of the Karzhan-Say River, on the northern slope of Karzhan-Tau Mountains, in the so-called Karzhansay formation. Vasil'kovskiy's description [4] of this formation takes only ten lines. According to his data, the block of extrusive and sedimentary rocks lies unconformably on the Oyasay formation, making shallow synclinal faults. The formation consists of (from bottom to top):

a) Sandstone pitching in the direction of strike; hundred meters thick;

b) Brick-red liparite porphyry; thickness 60 m;

c) Arkosic sandstone and acid tuff; thickness 20 m;

d) Light brown porphyrite lava; thickness 40 m.

Average thickness of rock, according to N.P. Vasil'kovskiy, is 130 m.

According to A.B. Kazhdan, a distinct unconformity between this block and the underlying block of the Oyasay formation has not been observed. The section is identical to the section of the upper Oyasay formation, which outcrops several kilometers to the west on the watershed of the Karzhan-Say and Chek-Karzhan Rivers. Taking into consideration these observations, we do not see any reason for the separation of an independent Karzhansay formation and we are including these rocks in the upper Oyasay formation.

Analogous conclusions were given by N.P. Vasil'kovskiy [5] in his last article.

SHURABSAY FORMATION

The Shurabsay formation was first recognized by N.P. Vasil'kovskiy in the Karzhan-Tau Mountain Range where it is widely distributed. Similarly extensive deposits are distributed in the Chatkal' Mountain Range, but they are considerably less extensive in Kuramin. An intense phase of tectonic and magmatic activity preceded deposition of the Shurabsay formation. Due to this fact, the formation lies in sharp angular unconformity to rocks of different content and age, beginning with limestones of the Upper Devonian, the Lower Carboniferous, and ending with Upper Carboniferous deposits. The block of basal conglomerate, tuffaceous conglomerate, sandstones, tuffaceous sandstone, and other extrusive and sedimentary rocks is present everywhere at the base of the Shurabsay formation.

The most complete section of Shurabsay deposits occurs on the northern slope of Chatkal' Mountain Range, in the basin of the Aksak-Ata (left bank of the river), Parkent, Zarkent Rivers, and also on the southern slopes of the range in the basin of the Karabau and other Rivers. For all these regions, I.P. Kushnarev has set up the following section (from bottom to top).

1. Basal conglomerate, tuffaceous-conglomerate, interbedded with sandstone, tuffaceous sandstone, tuff, tuffaceous breccia, and separate interlayers of porphyrite, limestone, limy and bituminous shale. Numerous investigators have found in these interbeds many plant fossils, which were identified by A.N. Krishtofovich and T.A. Sikstel'. They include Sphenopteris sp., Phyllotheca sp., Walchia piniformis Stern., Ullmannia biarmica Eichw. (abundant), Voltzia sp., Risodendron angrenicum Kryscht., Samaropsis sp., Dorycordartes pancifolia Schmalch., Callipteris sp., Rhachiopteris sp., Phyllotheca sp. ex gr., Ph. sulvensis Zal., Neuripteridium sp., Glossopteris sp., Pterophillum sp., Baiera sp., Neogerathiopsis sp., cf., N. orta Zal., Dicranophyllum sp., Pholidophyllum sp. and other forms, undoubtedly indicating the Early Permian Age of these deposits. Their thickness is variable: from 10 to 5 m in the region of Bash-Kyzyl-Say to 350 to 380 m in the Aktash Mountain (upstream from Zakent); usually it is about 250 m.

2) Red-brown and violet-brown andesite porphyrite, more rarely andesite-dacite porphyry and tuff, with rare, thin interlayers

of lava breccia of quartz porphyry and tuffaceous conglomerate. Thickness of this block ranges from 250 to 430 m.

3) Red-brown conglomerate, tuffaceous conglomerate, lava breccia, and porphyrite, rarely quartz porphyry tuff; thickness 250 to 350 m.

4) Grey and brown-green-grey andesite porphyrite - 300 m thick.

5) Block of interbedded lava breccia and andesite porphyrite tuff, sandstone, tuffaceous conglomerate - 600 m thick.

The total, maximum thickness of these formations reaches 2,000 m. These five blocks are separated according to the prevalence of sedimentary or extrusive and sedimentary rocks. The sedimentary blocks are characterized by good stratification and softer relief; extrusives are combined into non-stratified massifs and stand out in relief because of their sharp, almost perpendicular slopes. These blocks are traceable in the field over great distances and are seen distinctly on airphoto maps.

The described sections are characteristic for all remaining rock types of the northern slope (left banks of Aksak-Aty, Maygashkan Mountain Range, Karankul'-Say Basin) and Karzhan-Tau Range. However, for these regions gradual and regular changes exist in the separate blocks. For example, for the northern slopes of Chatkal' Range, according to I.P. Kushnarev, the size of fragments and their thickness is changes in the lower basal block, but their general form is preserved. In places, small interbeds of limestone or limy-carbonaceous and siliceous shale are present. The second block of Shurabsay formation underwent more local changes. At the divide of the watershed of the Aksak-Aty River (Uch-Dzhaylyau region) the second porphyrite block is terminated with brown felsite and lava breccia, 30 to 40 m thick. The felsite is traceable to the west to the Kumbel' deformation (Ak-Kul' settlement). With the increase in thickness of the acid rocks to 360 m felsite lava breccia grow in importance. Here, the necks of large volcanoes that emitted acid lava have been recognized. All this results in an increase in the total thickness of the second block up to 600 m. To the west, north (Maygashkan Range) and south, i.e., in the axial part of the Chatkal' Range, the thickness of acid rocks decreases almost to zero.

The third block north of the index section of the Shurabsay formation is marked by the prevalence of fine, fractured sedimentary rocks over the extrusives. Thin interlayers of limestone are common here.

The fourth block has been spared from erosion only in the Maygashkan Range, where it lies conformably on the third block and is represented chiefly by quartz porphyry lava breccia. These rocks consist of a very great number of chiefly small, (usually 3 to 5 cm) fragments of limestone, shale, sandstone, porphyrite, felsite, and other rocks cemented by red-brown, in places dark grey, quartz porphyries. In places, thin dark grey or greenish-grey sandstone conglomerate porphyrite, and lava breccia occur among this lava breccia. N.P. Vasil'kovskiy and K.N. Vendland have called these rocks quartz porphyries of the Maygashkan type and assumed that they are part of the Kyzyl-Nurin formation. The fifth block in this region is eroded.

In the Karzhan-Tau Mountain Range, according to A.B. Kazhdan, on the slopes of Myn-Bulak Mountain, the lithology and thickness of the three lower blocks of rocks is the same. In the upper part of the section, corresponding to the previously-mentioned fourth and fifth blocks, coarse, fractured tuff, tuffaceous breccia, tuffaceous conglomerate, and tuffaceous sandstone of brown, greyish-green, and reddish-violet shades prevail. The section of the Shurabsay formation of Karzhan-Tau Range is completed by reddish-violet quartz felsite porphyries, 100 m thick. Therefore, in the Karzhan-Tau Range, starting with the third block, fragmental pyroclastic extrusive material prevails. Maximum thickness of the formation reaches 2,000 m.

Distribution of Shurabsay deposits in the Karzhan-Tau Range, according to A.B. Kazhdan, is considerably greater than that recognized by N.P. Vasil'kovskiy and K.N. Vendland. By direct tracing of the basal blocks in higher beds of the Shurabsay formation, exposed on the north slopes of the range (of Karzhan-Say basin), this formation is known to continue up to the watershed range and farther on the south slope to the headwaters of Karakiya, Aktak, and Shurabsay. The Mynbulak Mountain section, described previously by N.P. Vasil'kovskiy as the type section of the Mynbulak formation, is the uninterrupted continuation of the Shurabsay formation, recognized by N.P. Vasil'kovskiy in the basin of the Shurab-Say River and on the south slope of this range. Besides, a considerable area on the south slope of the Karzhan-Tau Range is included as part of the Shurabsay formation, based on detailed tracing of its separate units along the strike, where rocks described by N.P. Vasil'kovskiy as Akchinsk are exposed.

On the south slope of Chatkal' Range, i.e., on the right bank of the Angren River and between Kumbel' and Kenkol' faults,

ie three first blocks are preserved; and in laces even a fourth block exists, recognized y I.P. Kushnarev in the northern slope of hatkal' Range.

The most complete sections of the Shurabay formation are present in the region of ugava Lake and in the lower course of the ava-Say. In the region of Kugava Lake, the ection begins with basal conglomerate 100 to 50 m thick, above which are strata 1.5 km iick representing interbedded brown and iolet andesite and diabase porphyrite with iff, tuffaceous lava, and some sandstone nd tuffaceous sandstone. The section is ompleted by tuffaceous lava of brown or ght grey color. The Shurabsay formation in ie area of the Gava-Say differs from that of ie Kugalin section by the fact that over the asal conglomerate and sandstone with interds of Schwagerina-bearing limestone, a nit of brown tuff and tuffaceous lava of uartz porphyry appears; it reaches a thickess of 200 m and above this are alternating ndesite and diabase porphyrite, tuffaceous va and lava breccia with some interbedding conglomerate and sandstone, with a total iickness of more than 800 m. It is overlain the south by younger deposits. Total iickness of the Shurabsay formation here is ver 1,200 m. Exactly in this region, N.P. asil'kovskiy tries to explain, in his last ticle [5], his assumption on the younger eologic age of the Oyasay and Shurabsay rmations. Basing his correlation only on the ssociation of these rocks with acid extruves and pyroclastics, he is inclined to conder the block of these rocks, overlying the asal conglomerate interlayed with Schwagena-bearing limestone, as the Oyasay formaon. However, during the remapping of this gion in 1954, I.P. Kushnarev and A.F. tkin have confirmed that the basal conglomate interbedded with Schwagerina-bearing mestone lies unconformably on the eroded urface of Akchinsk, Oyasay, and Mynbulak eposits already separated by A.S. Makarov, .P. Artemova, and M.M. Lebed', and hers and, therefore, the block of acid xtrusives cannot belong to the Oyasay forення ation. Moreover, as was demonstrated bove, the presence of acid extrusives of onsiderable thickness between the beds of e Shurabsay formation has been observed many places. Especially common is the esence of such rocks in the second block bove the basal conglomerate (right bank of ksak-Ata, of Nurek-Ata, Ak-Bulak, and her river basins).

In regard to the assumed unconformity of .P. Vasil'kovskiy [5], inside the sedientary and volcanic strata in the Kassan, isha, Ata, and other river basins, no other vestigator of this region (including Bensh) is ever observed such unconformities; any factual data are also absent in the work of N.P. Vasil'kovskiy.

Therefore, according to our opinion there is no reason to revise the geologic age of the Oyasay (C_3) and Shurabsay (P_1) formations.

Relatively large areas of Shurabsay deposits occur in the Kuramin Range, and in the region of Tashkesken and Takeli Mountains. Here, as everywhere, they begin with basal conglomerate and sandstone, which change to intermediate, basic, and rare acid extrusives and pyroclastics alternating with sedimentary and extrusive and sedimentary rocks. Their thickness is not over 400 m. In the axial part and on the northern slope of the Kuramin Range, the Shurabsay formation is absent.

RAVASH FORMATION

The Ravash formation was recognized by N.P. Vasil'kovskiy and Z.P. Artemova in the axial part of the northern slope of the Chatkal' Range and in headwaters of the Ravash-Say and was also noted in the lower course of the Gava-Say, Tashkesken Mountain region (Kuramin Range) and other places. The reason for the separation of this formation is the sharp difference between the Shurabsay and Ravash formations, which occurs in the Ravash River basin and farther west in along the northern slope of the Chatkal' Range. No fossils were found in the Ravash formation; due to this, N.P. Vasil'kovskiy included it in the Upper Permian. The main section on which the separation of Ravash formation was based is present on the northern slopes of the Chatkal' Range, in the lower course of the Gava-Say, and in the region of Kugal Lake. According to its lithology and thickness, judging from the original description, it is similar to the section of the Shurabsay formation. The first region has been fully remapped by I.P. Kushnarev, the two latter ones by him together with A.F. Utkin. South of the Karabuzuk deformation on the northern slope of the Chatkal' Range, the basal unit of the Ravash formation of M.P. Vasil'kovskiy and Z.P. Artemova was found to correspond to the third extrusive and sedimentary block of the Shurabsay formation at the above-mentioned section. This unit was later traced by I.P. Kushnarev to the north and west of the Karabuzuk deformation, shortly, on all northern slopes of the Chatkal' Range in the area of exposure of the extrusive formation, i.e., far over the limits of the Ravash formation of N.P. Vasil'kovskiy. As a result, it is known that the deposition of this block is continuously conformable with only the second block of the Shurabsay

formation. Its thickness is between 300 and 400 m. As mentioned previously, the thickness of the second block was determined by the type of extrusive activity during its formation; therefore, the presence here of a sharp angular or any other type of unconformity between the second and the third blocks was not confirmed, although, according to N.P. Vasil'kovskiy, the boundary between the Ravash and Shurabsay formation is present here. The absence of any unconformity in this formation in the area of the northern slope of the Chatkal' Range can be seen clearly on air photos.

In his last work, N.P. Vasil'kovskiy [5] again tries to prove the presence of this unconformity by basing his argument on observations during his trip with I.P. Kushnarev to the region of Ravash Mountain and headwaters of Aksak-Ata. Omitting comment on certain errors in Vasil'kovskiy's description (the visited region is actually situated 4 kms farther northwest from Ravash Mountain, i.e., the watershed is between Ken'kotan-Say and Say-Tokali; Z.P. Artemova was not present. We have to note the following about the new data:

a) The note on "basal" conglomerate cutting the Ravash formation "folds" (expressed in well-stratified andesite porphyrite of the Shurabsay formation) does not correspond to reality. In andesite porphyrite not only is the stratification, but even the trace of mobility full absent, but lineations across several systems are widely developed. Exactly these lineations, where they are exceptionally well expressed because of erosion, have been accepted by N.P. Vasil'kovskiy as stratification;

b) In regard to cutting "by the base of the Ravash formation of a dense network of small quartz veins, cutting andesite porphyrite of the Shurabsay formation" -- these facts were not observed by I.P. Kushnarev and N.P. Vasil'kovskiy. To conform this important statement it will be necessary to introduce sketches and description of outcrops and veins with exact geographic locations;

c) The indication that "in the vicinity of Ak-Takhta Pass, the Ravash formation fully cuts the Shurabsay formation and west of this pass lies directly on the Oyasay formation" also does not correspond to reality. In this region an unconformable deposition of the Shurabsay formation (with basal conglomerate at the bottom and with an identical section to the Shurabsay formation on the axial part of the range) on Oyasay rocks. Below the basal conglomerate of the Shurabsay formation, a 200 m thick block of inner Oyasay porphyrite is present, which N.P. Vasil'kovskiy accepts only by macroscopic resemblance as the Shurabsay formation. He also fully ignores data of ours, and also the data of other geologists, on the fact that among extrusive rocks of the Oyasay formation and in many regions of the Chatkal' Range thick units of porphyrite macroscopically similar to the Shurabsay formation exist.

As indicated during the description of the Shurabsay formation of the Chatkal' Range, this section is also locally developed in the Karzhan-Tau Range according to A.S. Kazhdan. Therefore, in all that huge territory the same conformable strata are present; there are no reasons to separate a new formation from such strata. In regard to the downstream segments of Gava-Say, A.S. Makarov and P.N. Podkapayev noted that the Shurabsay and Ravash formations dip to the southeast at different angles; the Shurabsay formation at 40 to 45° and the underlying Ravash formation at 80 to 85°. Special investigation carried out here by I.P. Kushnarev in 1952, and then by A.F. Utkin together with I.P. Kushnarev in 1954, showed that close to the Fergana Valley, the angles of dip became steeper and steeper and without sharp increment reach the dip characteristic of the so-called Ravash formation; this also excludes the problem of unconformity of these beds. Therefore, we are encountering here in the section of the Shurabsay formation, a section very close in every respect to that of the northern slope of the Chatkal' Mountain Range. The increase in the angle of dip to the southeast we are inclined to explain by overlapping of Alpic deformation due to sharp deflection of the Fergan Basin, which has, according to preliminary geologic work, the Paleozoic basement at a depth of about 10 kms (near the Syr-Darya). Deposition of cretaceous sediments overlying the so-called Ravash formation and dipping southeast at 30 to 35° also confirms our conception.

In the region of Kugal Lake, superposition of the so-called Ravash formation on the Shurabsay formation has not been observed. The mapping of this same region, where this formation was recognized by N.P. Vasil'kovskiy and other investigators of his group, showed that the character of the section in this region and the number of unconformities permits separation here of only the Akchin formation, Oyasay formation, and Kyzyl-Nurin formation; there are no grounds for the separation of the Ravash formation.

I.P. Kushnarev has inspected the borders of the Kuramin and Chatkal Regions everywhere N.P. Vasil'kovskiy and other geologists supporting his stratigraphic scheme separated (often with reservations) the Ravash formation. There were no facts, which casts doubt on the general conclusion that in the territory

of the Kuramin structural-facies zone there are some grounds for the separation of the Ravash formation as an independent stratigraphic unit.

KYZYLNURIN FORMATION

The Kyzylnurin extrusive formation exists only on the margins of the Chatkal' and Kuramin Regions in the form of separate erosional outliers, and it is absolutely absent in Karzhan-Tau Ridge and Mogol-Tau Mountains. Its largest outcrops are present in the axial part of the Chatkal' Ridge west of Kumbel' fault in the region of Kugal Lake, and in Kuramin Ridge the largest exposures of this formation are located in the Chadak River Basin. Rocks of the Kyzylnurin formation lie with sharp angular unconformity on the peneplain surface of the Shurabsay and Oyasay formations, and in the region of Kugal Lake, according to I.P. Kushnarev and A.F. Utkin, even on Devonian strata.

The red and pink quartz porphyry, cutting all Upper Paleozoic extrusives was first identified in the region of Kyzyl-Nura Mountain (Chatkal' Range) by S.F. Mashkovtsev [9], who considered them the youngest Upper Paleozoic intrusives. Later B.I. Nasledov [12, 13] and A.F. Adelung [1] found that besides intrusive quartz porphyries in this massif large masses of rock of the same composition and texture, having a blanket form, are developed. Later still, Ye. A. Kochnev, N.P. Vasil'kovskiy, and Z.P. Artemova were able to determine here an unconformity between these sediments and other Upper Paleozoic formations. According to N.P. Vasil'kovskiy [4], the region of Kyzyl-Nura Mountain is made up of liparite porphyry. Only rarely in separate regions did he note at the bottom of this formation the pink spherolite-liparite tuffaceous lava and lava breccia passing into red liparite, above which the greenish grey spherolite porphyries reappear. The total thickness of this rock is 30 m. The total thickness of formations here ranged from 300 to 1,000 m, according to N.P. Vasil'kovskiy.

Investigation carried out in this region by I.P. Kushnarev showed that the composition of the Kyzylnurin formation here is more complex. He established the following stratigraphic section (from bottom to top):

1. Red-brown albitized porphyries, in places tuffaceous with scattered plagioclase of flesh-red color; thickness 28 to 30 m.

2. Red tuffaceous lavas of quartz porphyry; thickness from 12 to 20 m.

3. Ash-grey tuff -- 40 m thick.

The total thickness of the entire pyroclastic section is 80 to 90 m, in places it reaches 260 m (headwaters of Parkent-Say and Kyzyl-Say).

4. Massive pink and brownish-red quartz porphyries, thickness up to 800 m.

5. Dense brownish-red and brown conglomerate and coarse-grained, in places cross-bedded sandstone about 27 m thick.

In the pebbles of the conglomerate, different extrusive rocks are represented, including rare pebbles of quartz porphyry from the Kyzylnurin formation. These conglomerates occur as insignificant patches, 100 to 500 sq. m in area in the region of Kok-Takhta (left bank of Aksak-Ata River). Paleogene small-pebble conglomerate and sandstone, with carbonate and gypsum cement lie unconformably above these formations. The small area of outcrop of the upper sedimentary block of the Kyzylnurin formation does not permit a conclusion concerning its conformity with the lower block of this formation; they may be correlative with the bottom of the new formation. Arbitrarily, these sedimentary blocks of conglomerate and sandstone have been correlated with the top of the Kyzylnurin formation by I.P. Kushnarev.

A somewhat different section of the Kyzylnurin formation in the axial part of Chatkal' Range has been described by N.M. Kolmogorov, V.S. Lakman, M.Z. Zakenov, L.V. Khoroshilov, and other investigators of the Chauli River basin. Here the block of tuff and tuffaceous breccia, forming the bottom part of the formation, is only 5 to 20 m thick, but among the overlying quartz porphyry interbeds and small blocks (from 0 to 100 m thick) tuff and obsidian lava are present. The total preserved thickness of the Kyzylnurin formation here reaches 350 m.

In the region of Kugal Lake, A.B. Makarov, Z.P. Artemova, M.M. Lebed', Z.S. Rumyantseva and also A.F. Utkin and I.P. Kushnarev noted very inconsistent interbeds and lenses of tuffaceous conglomerate, also tuffaceous quartz porphyries, rarely tuffaceous sandstone 1.5 to 7 m in the base of the formation. The total thickness of these sediments is never over 15 to 30 m. The main mass of rocks is formed by brownish-red quartz porphyry up to 600 m thick.

The next region of broad exposure of the Kyzylnurin formation is the Chadak River Basin.

According to data of P.N. Podkapayev and

A.S. Makarov, completed and refined by A.F. Utkin, a peculiarity of this formation is that the composition and thickness of rock on both sides of the Kumbel' fault are strikingly different. On the northeastern side of the fault, the section is represented by quartz porphyry. Six hundred meters from the base of the formation of effusive-sedimentary beds around 150 m in thickness occur. At the base of this unit conglomerates are present which change at the top into greyish-green coarse-grained sandstone and grey tuff. In the pebbles of the conglomerate, besides the different extrusive rocks, fragments of the underlying quartz porphyry are present. Above the extrusive and sedimentary block, a block of quartz porphyry occurs; the quartz porphyry is analogous to the lower block and is 200 m thick. Therefore, the maximum thickness of the formation is 950 m.

On the southwestern side of the fault the lower block of quartz porphyry is completely absent and the formation begins with the unit of conglomerate and tuff, which is explained by I.P. Kushnarev by the movement of blocks along the Kumbel' fault during development of the Kyzylnurin formation; more clearly, before formation of the conglomerate and tuff unit, the southwestern block was lifted and the lower part of the Kyzylnurin formation was removed by erosion.

The sections of the Kyzylnurin formation, given here, demonstrate in the main region of its development a distinctly characteristic quartz porphyry texture, permitting easy correlation of distant outcrops of this formation. The other peculiarity of this formation is the partial preservation of the source of extrusion in some places; usually fracture extrusions of the blanket-type predominated over extrusions of the central type.

In several places, the blanket formations are eroded and it is possible to observe roots of the Kyzylnurin formation. These places are: foothill regions of the Kuramin Ridge north of Sangar village, region of Babaytaudor quartz porphyry massif, Parkent River, Bash-kyzyl-Say basins, and other places. On the right bank of Aksak-Aty River, a large dike has been described; this dike passes into blanket rock.

The lower border of the Kyzylnurin formation is determined by its unconformable contact on Lower Permian rocks of the Shurabsay formation, the upper border by unconformable deposition on it of Lower Jurassic coal-bearing deposits. The most probable age of this formation, therefore, is Upper Permian.

Conclusion

The new factual material on the stratigraphy of sedimentary-extrusive deposits of the Middle and Upper Paleozoic of the southwestern slopes of North Tien Shan' testify that at the present time the stratigraphic scheme offered by N.P. Vasil'kovskiy [4] should be changed. Our investigation confirmed the existence of only six of the eleven formations separated in the stratigraphic scheme of N.P. Vasil'kovskiy.

According to our data, there are grounds to separate only the following formations in the section of volcanic sediments of the Middle and Upper Paleozoic of the Kuramin zone:

Top of Lower Carboniferous and Middle Carboniferous

1. Mynbulak formation (or Uya formation) Namur series of Lower Carboniferous-Middle Carboniferous.

Upper Carboniferous

2. Akchinsk formation (probably upper part of Middle Carboniferous-bottom of upper Carboniferous).

3. Sarysiun formation (probably middle of Upper Carboniferous).

4. Oyasay formation (Upper Carboniferous).

Lower Permian

5. Shurabsay formation.

Supposed Upper Permian

6. Kyzylnurin formation.

There are no grounds to consider that among the carbonate sediments of Wise Series and volcanic Namur sediments of the Mynbulak formation (Uya formation), an interruption in deposition had occurred and a tectonic-magmatic phase developed. In this respect we fully share the opinions of V.M. Veber who recognized the conformable sequence of limestones of the Lower Carboniferous and extrusive rocks. We also deny the existence of the so-dalled "Pre-Ravash" tectonic-magmatic phase, because there are no grounds on which to separate the Ravash formation itself.

The recognized formations differ from each other by particularities of lithology, mode of sediment accumulation and volcanic activity, and they are separated from each other by distinct unconformities. Therefore, there are no reasons to unite the different formations into extrusive-sedimentary complexes. Thus, the Aktash complex, separated by N.P. Vasil'kovskiy including the Akchinsk, Sarysiyun, and Oyasay formations, consists of

distinctly different sedimentary-volcanic rocks and is divided by two large regional unconformities between the Sarysiyun and Oyasay formations. The same holds true for the Aksakatin complex, which, according to N.P. Vasil'kovskiy, unites the Shurabsay, Ravash, and Kyzylnurin formations.

The factual material collected by us forced us not only to reduce the number of formations but also to change our concept of their lithology, facies, thickness, and distribution. Therefore, the geologic map of the region, compiled by N.P. Vasil'kovskiy's group, has undergone considerable change. This becomes fully clear if one considers that up to the moment of compilation of separate plane table sketches, a single stratigraphic scheme was not yet in existence and the correlation was done by N.P. Vasil'kovskiy on the basis of separate traverses. Besides, in our opinion, during the plotting of separate plane table sketches and the composite map, the investigators did not pay sufficient attention to direct tracing along the strike of separate units, which is absolutely necessary during the mapping of sedimentary-volcanic complexes changing in content and facies. In the meantime, during the correlation of separate sections from different regions, N.P. Vasil'kovskiy overestimated the potentialities of the method of petrographic comparison which resulted in errors in the correlation of separate units and even formations.

Greatly exaggerated use, by N.P. Vasil'kovskiy, of the method of petrographic comparison is also demonstrated in his last article [5].

The great number of errors is due to the fact that during mapping, the zones of tectonic disturbance were not generally traced along the strike and some of them were even mapped only in explanation of the gap in the geologic section in adjacent regions.

It is absolutely evident that in geologic work in such a complex region, for which until recently even the most general stratigraphic scheme could not be computed due to broad development of very different extrusive rocks, discrepancies and errors were inevitable during the first stage of investigation. In conclusion, we consider it necessary to stress again that our work has been largely facilitated by the presence of voluminous factual material collected by the organization of Central Asian geologists and interpreted by N.P. Vasil'kovskiy.

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SOME PROBLEMS OF MODERN PETROLOGY[1]
(THE SECOND ALL-UNION PETROGRAPHIC CONFERENCE)

by

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The Second All-Union Petrographic Conference, devoted to problems of modern petrology, will take place in Tashkent in May 1958. This conference is on new developments of geologic theory and undoubtedly will be a significant step in the development of petrographic science, particularly in creation of a theory of endogenic mineralization. This conference will be particularly important for the Central Asian geologists, who have already been partly successful in the solution of problems in general petrology and related problems of magmatism and endogenic mineralization in Central Asia.

The First Conference of Petrographers, which took place in 1953, was prepared with direct participation of the famous petrographer, the late D.S. Belyankin, the student of F.Yu. Levinson-Lessing, the prominent Soviet petrologist. F.Yu. Levinson-Lessing and D.S. Belyankin had assisted tremendously in the development of petrology and carried out fundamental investigations in the most important parts of this science.

The works of the greatest Soviet petrologist, A.N. Zavaritskiy is a glorious page in the theory of formation of magmatic rocks and endogenic ore deposits. Problems of petrography and the theory of mineralization have attracted the attention of other outstanding scientists, for example, A.Ye. Fersman and S.S. Smirnov, who contributed greatly to these subjects. Petrology of magmatic rocks and related ore formations is the focal problem of today in theoretical investigations of Soviet geologists. Only 5 years have elapsed since the first petrographic conference, but many interesting materials and valuable conclusions have accumulated from large-scale, mostly regional, petrographic investigations.

Many advances in knowledge resulted from petrologic investigations in Central Asia. The first generalization on magmatism and endogenic mineralization was made here by V.A. Nikolayev, A.Ye. Fersman, and G.I. Shcherbakov. Theoretical geochemical investigation was also started here by V.A. Nikolayev.

The large group of the young geologists working in adjacent fields of contemporary petrology and ore genesis and developing petrogenic and metallogenic concepts have been organized in recent years in Central Asia, particularly in Tashkent and other geologic centers. Here we have to note the works of R.B. Baratov, K.L. Babyev, Kh.M. Baymukhamedov, A.B. Batalov, S.B. Babakhodzhayev, O.M. Borisov, Ye.M. Golovin, O.P. Gor'kovoy, I.M. Isamukhamedov, M.S. Kuchukova, A.A. Malakhov, T.M.M. Matsokina, I.M. Mirkhodzhiyev, R.A. Musin, R.Sh. Radzhabov, M.Kh. Khamidov, I.Kh. Khamrabayev, A.Kh. Khalmatov. They are working for the solution of problems of petrology and mineralization in a complex way, studying geologic phenomena and chemical composition of magmatic rocks as well as magmatic processes connected with magmatic complexes.

Collective discussions of acute problems of science, undoubtedly contribute greatly to theory and practice; therefore, it is desirable that conferences on petrology be held regularly and become part of the tradition of Soviet geologists.

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[1] In connection with the Second All-Union Petrographic Conference of May, 1958, we are publishing in this issue an article by Kh.M. Abdullayev, President of the Organizing Committee of the Conference. Additional valuable material for the conference, the analysis of the condition and goals of national petrography, was treated recently in articles by S.P. Solovyev The Basic Achievements in Petrology in the Last 40 Years (1917-1957) (Zap. Vses. Mineralog. O-va, 2-ya Seriya. Ch. 86, Vyp. 2, 1957) and in the article Certain Geological Problems in Petrology by V.D. Afanasyev (Izv. Akademiya Nauk SSSR, Ser. Geol., no. 11 1957).

I with to draw to the attention of the readers the problems which, from my point of view, are worthy of particular attention in discussions at the coming conference.

1. IN THE STUDY OF GEOLOGY OF MAGMATIC ROCKS, INTRUSIVE BODIES AND EXTRUSIVE FORMATIONS, the petrologists of the world and particularly of the Soviet Union have made great advances. Structural and regional geologists also play a large part in the knowledge of the geology of magmatism. By common efforts the age sequence in the formation of different magmatic rocks in terms of size and content has been established for several vast regions; the most important tectonic-magmatic complexes have been recognized, and these complexes are characteristic of different stages of development of zones subject to deformation; the first steps were made in studying small intrusives as a unique form of expression of magmatism in the final stages of development of mobile zones; the determination of absolute age has been started. However, many problems are not yet clear and require the organization of special investigations. Such problems are:

a) Morphology of intrusive bodies and their influence on postmagmatic productivity of magma;

b) The roll of tectonics not only in the wide but also in the narrow sense, in concrete cases; the influence of tectonic conditions during the period of intrusive injection of magmatic rocks, and on the character of post-magmatic products; the mechanism of magmatic injection in tectonically active and inactive zones;

c) Development of criteria for age and stratigraphic classification of intrusive rocks with extensive work on determination of absolute age;

d) Expression of depth factors in classification of intrusives and the role of facies of these intrusives in postmagmatic phenomena.

Besides these problems on materials of complex geologic studies the concrete role of geologic environment in movement and localization of magma and other peculiarities of formation of intrusives should be established.

The most important local petrologic problems include the detailed study and determination of regularity in penetration of magmatic complexes and their connection with the structural development of separate regions. It is necessary to admit that Yu. A. Bilibin has only initiated such study and his classification of mobile zones is too general; it can be applied only during analysis of regional problems. It is already time to move from this general scheme to the analysis of specific mineral regions, developed in different structural environments. With such an approach it is possible that different genetic types of mineral regions and, consequently, different schemes of development of magmatic ore complexes could be established.

In general it is necessary to stress, as stated by F. Yu. Levinson-Lessing [3], that the solution of many problems of modern petrology depends on the organization of general geologic observations and on regional geologic and geophysic investigations.

2. CAREFUL STUDY OF THE COMPOSITION OF MAGMATIC ROCKS, ESPECIALLY EXTRUSIVES was and remains one of the main problems of contemporary petrology. Much has been done in this direction. In the last 60 to 70 years petrographers from all countries worked hard to study the chemical and mineralogic composition of rocks and to determine their dependence on conditions of formation. Every new stage in study of the classification of rocks brings its own characteristics into this, the oldest, but not always most acute problem.

At present great significance is attributed to the study of accessory minerals, and separation of the elements of magmatic rocks as stressed by D.S. Belyankin [1] in his introductory speech at the First Petrographic Conference. Special attention, we think, should be centered in future petrographic investigation on the following topics:

a) The composition of placers, especially for heavy fractions, from the matrix rock;

b) The behavior of different minor elements in distinct rock-forming and accessory minerals; wide and profound study of geochemistry of magmatic and postmagmatic formations, on which depend the solution of many problems of petrology and the theory of ore formation, is also necessary;

c) Geo-chemical analysis of mineral facies of magmatic rocks, similar to that which has been done in series of works on metamorphic rocks;

d) Special study and generalization of data on petrochemical analysis of magmatic rocks for the most important petrographic regions; in particular, establishment of the relationship between chemical content of extrusive rocks and the lithologic and chemical composition of the country rock.

We cannot fail to recollect the correctness

of A.N. Zavaritskiy's note [2] that "geochemistry has its own particular problems and its own particular methods, and our knowledge of the chemical composition of rocks is not the only material for geochemical study of the methods of formation and origin of rocks".

So, the wide acceptance of the problem of geochemical investigation of magmatic rocks is of a great practical importance.

3. THE ROLE OF MAGMATIC PROCESSES IN FORMATION OF ENDOGENIC DEPOSITS OF NATURAL RESOURCES AND CRITERIA FOR ESTABLISHING RELATIONSHIPS BETWEEN THEM is the most acute and complex theoretical problem in all contemporary geology. The great importance of magmatic rocks in endogenic ore genesis is universally accepted.

In recent years, different forms of expression of these relationships have been discovered, thus the reliability of certain criteria is stressed, and intersecting discussions in the press and at special conferences and conventions have developed. Meanwhile, there is much in this region which is still undecided and disputed. The more we study this problem the more facts on these relationships are found, the better expressed are unclear and incomplete parts of this problem. The study and definition of this problem should be carried out with the consideration of the problem on endogenic mineralization.

Five years ago, D.S. Belyankin sorrowfully noted that magmatic petrography, due to its separation from the practices of mining ore deposits, has become too theoretical in character, and this developed to a certain degree into a kind of retardation of petrography and lack of appreciation of its importance in our practical work.

In recent years, thanks to wide discussion of the genetic relationship between mineralization and extrusive activity, petrographic investigation has acquired greater scope and now occupies a proper place in our work. However, because the general problems still prevail in discussions on genetic relationships, now is the time to strengthen the concrete investigation of separate regions, provinces, and types of deposits.

1. Generalize existing materials in respect to the relationship between separate provinces, regions, and types of deposits.

2. Find the petrographic and geochemical symptoms of relationship as the main part of the problem in this stage of the study.

3. To study the problems on genesis of deposits far from the source of magmatic complexes.

In total, it is necessary to show the whole complexity and variety in form of the problems of ore genesis and petrology.

The origin of ore-bearing and other intrusive rocks and the factors affecting their origin are still not known. At this stage of our knowledge the geologic part of the problem becomes important; i.e., an investigation of the part of regional geologic factors in postmagmatic magma activity is important.

Long ago I had noted that potential mineralization, at least in acid magma, can be realized in the form of postmagmatic solutions and deposits only under favorable geologic and geochemical conditions. The problem now is to demonstrate the part tectonic, lithologic, plutonic, and other geologic factors play in postmagmatic activity of magma.

4. THE GENESIS OF ROCK HAS BEEN AND REMAINS ALSO ONE OF THE MANY PROBLEMS OF PETROLOGY. Here we still have no generally accepted theory but different opinions supported by one or another investigator. At present an uninterrupted accumulation of factual material, its analysis, and preparation through formulation of general theory, is taking place. Petrology is still in the stage of development and perfection of its scientific foundations, still in the stage of scientific search.

At present very important regularities in geologic phenomena, of great importance for theoretical and practical work, are being established. The lack of a generally-accepted theory, therefore, testifies not only to the complexity and variety of the problem but also to the urgency of petrologic problems, and constantly reminds us of the necessity for continuous effort in our work.

Even the greatest Soviet theoretician, F.Yu. Levinson-Lessing [3] stated that "I do not have at present such a categoric theory as in 1910, but to avoid misunderstanding and prejudices it is better to accept that no one theory can fully satisfy us". Further he showed that, naturally, his opinion has been changed during decades.

Those words were written more than 20 years ago. Material accumulated during this time and certain conclusions testify to the correctness of F.Yu. Levinson-Lessing's opinions. The problem centers around accumulation of the facts which permit us to avoid simplification and help us outline all the different processes of formation of

magmatic rocks.

It is also necessary to account for the fact that our specific conclusions could be to a certain degree subjective. Very often a petrographer's opinions are determined by geologic originality of one or another region, or the process, with which the petrologist deals.

Tolerance of different opinion, which accepts different processes of rock formation is an important condition for the development of petrology as a science.

Undoubtedly, however, this series of problems needs further study and discussion. These problems include:

1. The importance of different geologic factors in the variety of magmatic rocks. It is generally accepted that the number of magmatic rocks is several times larger than the variety of magmas. Therefore, the study of the reason for such variety should be the topic of attention. The method of solution of this problem should be geochemical and geophysical experiments and theoretical work, in particular the determination of the part played by pressure and temperature, the number of volatiles, and the role of alkali in magmatic processes. It is necessary to study the limits of solubility for volatile and nonvolatile compounds; in the meantime, the investigations of recent years have been limited only to the determination of solubility of water in magma.

2. The importance of magma evolution at the place of intrusion; the role of differentiation and assimilation in the places of transformation of magma into magmatic rocks.

3. The role of enclosing rocks in developing petrographic variations and the study of the form of expression for the processes of assimilation in a wide aspect, including contamination, magmatic substitution, etc.

4. The importance of metasomatic and metamorphic processes in the variety of magmatic rocks.

It is possible to assume that study and expression of the role of assimilation, and particularly of metasomatism, will bring clarity to many troublesome problems on the origin of magmatic rocks and will help to determine the role of different types of differentiation. In regards to the last, it undoubtedly is considerably smaller than was considered until the present. The efforts to explain all varieties of magmatic rocks only by differentiation can lead us to a dead end, but will not solve this complicated problem. The role of differentiation should be clearly outlined in our minds.

Origin of magmatic rocks of monomineral content remains a special problem. In the most important problems it is necessary to understand the genesis of alkalic rocks and their metallogenetic importance.

A comparative study and a comparison of petrographic data of different provinces also deserves attention. The study and generalization of materials according to petrographic provinces of the USSR is undoubtedly a very important problem for the understanding of geology and ore genesis of the Soviet Union as well as for the treatment of general theoretical and practical problems of modern petrology. The publication of monographic investigations on petrology of Ural, Altay, Georgia, Azerbaydzhan, was, undoubtedly a very important stage in understanding the geology of the Soviet Union.

The First All-Union Petrographic Conference, accounting for the lag of regional investigation, made an appeal to the geologists and scientific establishments of the Soviet Union to increase such work. However, up to the present, very little has been done in this direction. The Second All-Union Petrographic Conference should once more stress the necessity of increasing investigation in separate petrographic provinces and completion of monographic studies.

The publication of books on petrology of different regions, especially those reporting the application of new methods of investigation could greatly encourage the development of petrology.

5. The problems explained are of equal importance for all types of intrusive and extrusive formations. However, the experience of Soviet geologists has already shown there are several problems which are worthy of special attention and thorough study. These are the problems of dikes, small intrusives, and, finally, of determining the metallogenetic importance of extrusive rocks.

The first generalization should be made on dikes through the publication of the results of investigation in different regions. Further study and demonstration of their metallogenetic characteristics will undoubtedly aid in reaching the right solution to many problems of modern petrology and ore genesis. This is especially true in regard to genesis, place and time of dike development, geologic relations of aplites and pegmatites, etc.

The metallogenetic importance of small intrusives is also basically important. An additional criterion should be established,

which would permit distinctions between small intrusive porphyries and those small intrusives which occur in the early stages of the development of the mobile zone, from batholiths, or in late stages of the formation of batholiths.

While there are certain works on dikes and small intrusives, the importance of extrusive rock in ore genesis is still discussed very little in the literature. The solution of this problem, however, would allow development of a perspective on the mineralization of certain regions, and would bring clarity to the problem of genetic relations of mineralization with intrusions and would promote understanding of ore genesis of separate regions.

We think, that in the marginal areas, between the different geologic sciences, one can expect the solution of the most important and controversial problems. Experience shows that at the modern level of development of knowledge, many problems of petrology and endogenic mineralization need investigation by overlapping sciences, i.e., petrography and ore genesis.

Working precisely in this direction, I am coming to the conclusion that we need an increasing number of such investigations. This branch of science, i.e., the region intermediate between petrology and science of mineral resources, can be called petrometallogeny. Such disciplines can exist and develop as independent branches of contemporary ore genesis.

In petrometallogenic investigations there are many interesting, new and practically important materials. It is already impossible to solve the problem of ore genesis in relation to the origin of dikes only on the basis of our knowledge of mineral resources or petrology. Such problems should be solved on the basis of data from both scientific branches each using their own methods and considering their conclusions. The broad approach and an increase in scale of investigation in the intermediate branches of science should occupy the proper place in our geologic work.

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REVIEWS AND DISCUSSIONS

F. K. SHIPULIN

ON THE BOOK OF KH. M. ABDULLAYEV "DIKES AND MINERALIZATION."

The book recently published by V.I. . Smirnov is called Dikes and Mineralization, and is written by Kh. M. Abdullayev; it deals basically with the relationship between mineralization and magmatic rocks and processes, a subject to which two editions of his famous book Genetic Relation of Mineralization to Granitoid Intrusions (1950, 1954) were already devoted.

The new work differs considerably in the treatment of the problem of the relationship of mineralization and intrusions, and deals chiefly with a narrower part of this problem: genesis and systematization of dike formation and their evaluation with respect to ore genesis. The book is of great interest to a broad circle of Soviet geologists, because it is of great value for its collection of vast factual material on the formation of dikes of many regions of the Soviet Union and foreign countries, collected and published during recent years.

The book consists of a short forward (that of the author), the introduction, ten chapters which are illustrated by about one hundred sketches and photographs, the conclusion, and the bibliography. The book is nicely printed, and the numerous illustrations facilitate considerably the reading and understanding of the text.

The following is a review of the content of the book chapter by chapter.

In the introduction (pp. 5 to 8), the author outlines the fundamental problems, the solution of which is the aim of the work; he gives the classification of rocks according to their dike origin; lists the chief studies on the formation of endogenic mineral forma-

[1] Gosgeolizdat, 1957, 232 pp.

At first the author gives a definition of the term "dike", which is generally correct, but not too precise. He writes thus: "the term 'dike' is understood to include the large group of geologic bodies original in form, formed by the filling of tectonic fractures by magmatic or similar rocks, metasomatic formations, and also by sedimentary materials" (p. 5). The author is in particular, inaccurate in dealing with metasomatic dikes, which are formed not by the filling of fractures, as follows from the text of the book, but by the substitution of primary rocks along fractures or other disturbed zones.

The genetic systematization of dikes offered by the author is the subject of the most serious discussion. Although this problem is especially dealt with in Chapter VII we will discuss the classification here because it determines the initial position of the author on the method of description of dikes. The author distinguishes three groups of dikes according to the mode of formation: endodikes (fractures filled with magmatic lava), metadikes (the metasomatic substitution), and exodikes (fractures filled with sedimentary material). This classification of the fundamental genetic groups need not be discussed because it was established long ago in the literature, but it is hardly necessary to introduce the abovementioned Greek names for this group. The word "endodike" means literally "dikes formed inside or at the depth". However, not only magmatic but also metasomatic dikes are formed under plutonic conditions and the term "endodike" loses its precision. The name "metadike" is also not very exact for dike-shaped bodies formed metasomatically, because the word "meta" is commonly used in geologic literature as a prefix for rocks subjected to metamorphism (for instance, metadiabase, metaeffusives, etc.) therefore, this term might be ambiguously interpreted. Further on, probably for greater clarity, the author himself used the names of "magmatic" and "metasomatic" dikes, but not endo- or metadikes. The term "exodikes" is more correct, tions; and, finally, determines the place of magmatic dikes in relation to other magmatic formations.

but considering the already widely used term "sedimentary dikes" it is probably much better to preserve this old term without using the new foreign word.

More serious errors were permitted in the classification of magmatic dikes. The author names three genetic classes:

1) Perimagmatic dikes (satellites and apophyses of the big massifs);

2) Intramagmatic dikes, divided into: a) sub-intrusive and b) post-intrusive;

3) Hypomagmatic dikes, subdivided into three types: a) plutonic, b) sub-extrusive, and c) sub-intrusive.

The main principle of division into classes is not followed in this classification of magmatic dikes. For example, the first two classes of dikes, related to a single magmatic source, are distinguished on the basis of their age relation with the mother intrusive (the dikes of the first class are formed simultaneously with the penetration of intrusives, the dikes of the second class are formed later in the period when the intrusion is arrested), and the third class is related to independent plutonic magmatic sources. Therefore, the basis for distinction of the first two classes is time, but the separation of the third class from the first two is based on different magmatic source and different position in space. This results in the concept that from a genetic point of view there are no considerable differences between dikes of the first class and synintrusive dikes of the second class, because they both are intrusions from an undifferentiated melting mass of the major mother intrusion squeezing laterally into host rocks or are crystallized endocontact intrusives. They also have no differences in composition; they both correspond in composition to the mother rock, which is stressed by the author himself on page 127. They are both so-called aschistic vein formations according to the general terminology accepted at present. It is hardly necessary to distinguish them as two different classes.

As the second type in the class of intramagmatic dikes, Kh. M. Abdullayev separates "the post-intrusive" dikes of aplite and pegmatite. Genetically, these intrusives represent a special group of so-called split or diaschistic dikes, and their inclusion in the same class with unsplit rocks is not justified at all on the basis of genesis. It is also necessary to note that the name "post-intrusive" for aplite dikes cannot be considered as correct, because they are actually intrusive.

And finally, the third class of dikes separated by the author is genetically more heterogeneous than the second. In this class the author unites dikes playing completely different roles in the history of development of tectonic magmatic cycles. Genetically, the sub-extrusive and sub-intrusive dikes are not independent types: they are closely linked, the first with extrusives and the second with intrusives, but the plutonic dikes are independent geologic bodies not directly connected with extrusives or with the major intrusives. In common to these formations are only their magmatic sources, which are situated at considerable depth, although they could be very different. It seems that the dikes are placed in the same class not according to their genetic semblance, but only by distance from the source. In this case, one might ask why the author does not also place in this class those dikes of the intramagmatic group, which, as shown on page 127, can well be "the independent segregation of more deeply situated magmatic sources"?

It is evident that this classification of magmatic dikes is not logically consistent and is not strictly genetic, and, therefore, the author himself in some cases is compelled to use the other more convenient method of classification. For instance, on page 31, in discussing the relation of magmatic dikes to intrusive and extrusive formations, the author gives the following systematization of dikes: "1) Dikes closely linked with intrusives; 2) Dikes which are developed independently from batholithic intrusives and subdivided into plutonic dikes of granitoid rocks and plutonic dikes of basic rocks; 3) Sub-extrusive dikes, related to extrusive formations".

This classification of dike formation according to genetic principles has been supported by us several times previously, and it is evidently this basis on which the genetic classification of magmatic dikes should be built. In the meantime, it will be good to divide magmatic dikes into series or groups according to their relation to distinct basic, ultrabasic, alkali, and acid magmas; then the dikes correlated with the major intrusive (schizolite), and corresponding to Broegger's proposition, should be divided into aschistics (unsplit, equivalent to rocks of the mother intrusion) and diaschistic (the split rocks). For the plutonic dikes and the other small intrusives originating in deep sources and not connected with extrusives or with the major intrusive, the term "small intrusives" has already been accepted. Finally, regard- the feeding channels of the lava extrusion, which are not only dike-like but have other different forms (pipes, necks, etc.), the term "sub-extrusive intrusion" can be

expediently used.

The author's statement on page 7 that dikes are not independent geologic formations and that they "cannot be separated in analogy with extrusives and intrusives into independent facies" is considered correct only in respect to schizolite, i.e., vein rock, directly connected with the major intrusives, and the sub-extrusive formation; but it is not correct in regard to the small intrusives (plutonic dikes) which are already separated and were seriously studied recently, when it became evident that they, independent from magmatics, comprise an important element of geology in many regions. The small intrusives demonstrate traces of independence in content and distribution from the major intrusives and extrusives usually related to the large linear fractures and penetrated deep into the earth. Together with extensive post-batholithic small intrusions in some regions, the pre-batholithic small intrusions are widely developed (northeast of U.S.S.R., etc.). They sometimes form large series of dikes and small bosses sometimes tens or hundreds of kilometers long along the strike; the small intrusion, in summary, becomes entirely comparable with batholithic body. Evidently, to neglect these small intrusions in their right to be considered as special geologic bodies would be entirely wrong.

Completing consideration of the dike classification offered by Kh.M. Abdullayev, we must note that the relation, of the xenoliths of metasedimentary rocks enveloped by magmatic bodies to the dikes of sedimentary type (pp. 126, 133), is absolutely wrong. Such xenoliths are not the filling of fractures, as is required by the definition of dikes given by the author on page 5. According to the data of Walker and Paul Dervarte, the rheomorphic veins of Carru, even if they can be called dikes, are more correctly metasomatic, but not sedimentary, as characterized on page 133.

One more note is necessary concerning the first part of the work, which deals with the definition of "small intrusives". On page 5 the author writes: "regarding the definition of 'small intrusives' the author in this work keeps the original definition". Everyone may think that the author uses the original definition of small intrusives made by Yu.A. Bilibin, but as evident from the following discussion, this is not so. Therefore, it becomes unclear which definition the author gives to this concept which is defined differently by various authors (Yu.A. Bilibin, M.B. Borodayevskaya, F.K. Shipulin, and others).

Chapter I (pp. 9-14) is called "The Conditions of Dike Formation and Its Significance in Ore Genesis". Here, the basic stages in the history of the study of dike formation by Soviet and foreign geologists are discussed together with short critical notes on each paper. Unfortunately, the author neglected in this chapter the work of A.P. Vaskovskiy, 1936, who seems to have been the first to raise in our literature the discussion of the problem of the plutonic source of dikes of intermediate rocks in ore regions; he has also omitted the work of Yu.A. Bilibin and S.S. Smirnov on small intrusives, which certainly is worth special consideration, because there for the first time small intrusives were described as independent geologic formations.

We want to add to Kh.M. Abdullayev's criticisms of the work of O.S. Polkvoy and V.S. Koptev-Dvornikov regarding the position of dike formation in the intrusive process. In general, the division of vein rocks by dikes of the first and second stages is illogical genetically because both types are connected with different magmatic sources, and, therefore, are not characteristic of different stages of development of the same magmatic system; this was admitted by the authors themselves.

In fact, if dikes of aplite, pegmatite, and grantophyre appear, as a rule, in connection with every intrusive phase of granitoids, the the dikes of lamprophyre and different porphyries, or small intrusives, are characteristic only of the later stages of development of multiphase intrusive complexes, and are sometimes injected before the batholithic intrusive phase.

Chapter II, <u>Position of Dike Formation in the Tectono-Magmatic History of Geosynclines</u> (pp. 15-30), contains a brief description of the general development of geosynclines and history of formation of intrusives in them, including dike formation. This study of the general development of geosynclines compiled by a group of geologists from VSEFEI and completed by Kh.M. Abdullayev. This study was illustrated by a sample description of magmatic rocks in western Uzbekistan, eastern Trans-Baikal, and in other regions.

Chapter III, (pp. 31-56) is called <u>Relation of Dikes to Intrusive and Extrusive Formations</u>". According to the natural association of dikes with other magmatic bodies, the author gives here a description of dikes closely associated with intrusive and plutonic bodies other than batholithic intrusives; and also of the sub-extrusive dikes related to extrusives. For each of this type, concrete examples in separate regions are given. From the group of basic plutonic dikes the author discusses separately lamprophyres.

The lack of solution of many problems on geology and genesis of lamprophyres is quite correctly stressed. Unfortunately, the author has not given his own definition of the term "lamprophyre", evidently accepting the present conventional definition of these rocks as melanocratic vein rocks bearing femic minerals and having porphyritic varieties with dark colored minerals. In this case, however, we cannot understand why the author did not mention the absolutely unsatisfactory definition of lamprophyre of Gyumbel, Rosenbush, and N.A. Yeliseyev, given on page 70. Although the author stresses the questionable genesis of lamprophyres, he nevertheless accepts the conception that lamprophyres originate during magmatic differentiation in specific intrusives. The author writes on page 53: "the close relationship of lamprophyres with intrusives is believed to be justified" and on page 54: "the materials on hand confirm that lamprophyres in general, and particularly in their chemical composition correspond fully to plutonic intrusive rocks". However, a few paragraphs lower, on page 54, we are surprised to read "on the basis of what has been written here and in other chapters of this book the author considers it possible to describe the lamprophyre dikes as plutonic (because of the magmatic source)". This inconsistency in reasoning shows that the author does not clearly understand the problem.

In Chapter IV (pp. 57 to 68) Role of Structure in the Distribution of Dikes and the Scale of Dike Formation, considerable material is given which reflects the role of structural control in dike distribution, the variety of the form of expression of dikes, and their multistage development. According to the relation of dikes to different tectonic structures, the author divides all dikes into two groups in the first of which are the dikes occupying major fractures and regional fracture zones; the second group includes the dikes controlled by relatively small structures and intrusive bodies. This paragraph deserves some comment. On page 16 the author comments that "the dikes connected with major intrusives and controlled by local structures . . . being closely connected in time and genetically with intrusive magmatic activity, are genetically linked to folded structures and in a majority of cases originate simultaneously with folding. Therefore, the distribution of dikes of this type, in general, coincides not only with big massifs, but also with the folded structures". This concept is disputable. If certain dikes originate simultaneously with folding in the different stages of synorogenic intrusion, then this is an exception rather than the rule. The overwhelming majority of dikes are formed in the late stages of intrusion when fractures develop in the intrusive itself, as well as in the cherty country rocks. The form of occurrence of dikes indicates that basically filled fractures, but not the folded structures. The folded structures are characterized by sills and interstrata intrusions but not dikes, as is well known.

Concluding this chapter, Kh.M. Abdullayev suggests that dikes may be classified according to the structural condition of their origin. In this classification the fourth and fifth categories of dikes are strikingly inconsistent in terms of the fundamental principle, i.e., classification according to the controlling structures; also the second and sixth categories are unjustified. The author attempts to show that the fourth category dikes are "related to later fractures and fissures in different rocks", and the fifth - to "regional fractures and zone of fissures". It is evident that this distinction is wholly artificial, because in the first case we are dealing with later fractures, i.e., the conception of time is introduced, and in the second the author speaks about regional fractures, i.e., the conception of space is introduced. It is clear that the same dike complex can be referred to both the fourth and to the fifth categories. This classification is thus inconsistent.

The second and the sixth categories of dikes in this classification are distinguished according to structural symptoms and not according to the character of their relation to the country rock. The second category "dikes are connected to the contact surface between intrusives and the filling rock" and the sixth category consists of "dikes in interstices of earlier dikes". Therefore, a breach of the principle of classification is permitted by the author here also; classification according to the filling structure is not the main principle of classification, but the composition of the host rock. And, finally, the intrusive bodies of the first group which have a tabular form and are situated between sedimentary strata do not quite fall into the structural classification, because morphologically they are not dikes.

In Chapter V (pp. 69 to 101) On the Reasons for Petrographic Variety of Dikes, the recorded data on this question are discussed and many original materials and the author's views are given. The illustration of many examples of the dependence of dike content on the enveloping geologic material, which is especially expressed in relation to pegmatite and other acid dike rocks is valuable and interesting; the very distinct dependence of mineralogic composition of such rocks on the postmagmatic processes is also noted by the author. In characterizing the lamprophyres and other basic and intermediate dike

rocks, the author records numerous chemical analyses, many never before published. In regard to the conception of "lamrophyres" certain doubt should be cast on page 81, where rocks containing 47 to 49 percent quartz, 32.8 percent plagioclase, and 13.2 percent biotite, and tourmaline, apatite, rutile, zircon, muscovite, and magnetite, are said to be lamprophyres. Such a mineralogic composition, especially low in biotite, does not fit the lamprophyre definition.

Chapter VI, (p. 102 to 122), "Dikes of Complex Structure", is devoted to the general description of dikes from Middle Asia. This chapter is one of the most interesting in the book and contains a description of different types of structures and sequences of injection of complex and compound dikes. The basic conclusions are interesting, because in the majority of cases complex dikes are formed by the injection of plutonic lava at different times during the crystallization stage in the same fracture zone. The assimilation of country rock has left a certain imprint on the composition of dikes. In correspondence to the structure of complex dikes, the author distinguishes three genetic types: the single injection dike, the multiple injection dike, and metamorphic dike.

Chapter VII (p. 123 to 133) deals with the genetic classification of dikes, which has already been discussed above.

Chapter VIII (p. 134 to 190) The Relation of Dikes to Postmagmatic Mineralization is the largest in the book and most important in terms of the problems dealt with. At the beginning the author stresses the importance of studying the relation between dikes and mineralization and justly criticizes I.I. Tanatara who considers the determination of age relations between dikes and mineralization unnecessary.

The author gives numerous examples of the development of dikes formed before mineralization and stresses the problem of postmineralization dikes, supporting his contention with factual material from many regions of the Soviet Union and other countries to prove that pre-mineralizational, post-mineralizational and compound dikes are present in the old bodies, which is of certain significance because of the works of F.I. Volfson, who denies the existence of post-mineralization dikes.

When studying the correlation of dikes with skarn ore bodies, the author draws the conclusion that in separate ore fields skarns of different age develop, many of which are of different age than the dikes. The author correctly concludes that the process of ore vein formation and dike formation in many ore regions has a multi-stage, pulsating character.

Chapter IX (p. 191 to 212) "Genetic Link of Postmagmatic Mineralization to Intrusions Related to Dikes." The author develops in this chapter the general metallogenetic conceptions which have been the topics of his earlier works. In this chapter are the fundamental problems in metallogenetic classification of magma and the relationship of mineralization to intrusion is summarized in very brief form. We are glad to note that the author, quite apart from his previous position gives in this work due place to the metal-bearing ability of plutonic magma. He believes the metallogenetic classification of plutonic magma is necessary to solve the problem of the metal-bearing ability of magma. In this work, the correct evaluation of magmatic assimilation is reached; until now assimilation has been underestimated by many geologists.

Some of Kh.M. Abdullayev's conceptions discussed in this chapter are of doubtful validity. For example, on pages 203 to 204 it is said: "The author considers that the source of granite magma was formed during the maximum development of fold movements (pre-batholithic and batholithic stages). Gradually, the magmatic source developed with development of orogenic activity, and "calms down", probably at the moment of intrusion of small plutons and formation of plutonic dikes. In this relatively quiet source, crystallization and later differentiation started. The result has been the differentiation of granophyre, diabase, and other derivates (including, possibly, lamprophyres and other types)." Somewhat earlier, on page 202, the author says on the same subject: "Pre-batholithic small intrusions, evidently, testify to the initiation of a source of granite magma. The small intrusions and dikes of the concluding stages in geosynclinal development, very likely, testify to the last stage of action of the magmatic source."

From given quotations, it is evident that the author believes granitoid source initiation occurs during the period of maximum folded movements in geosynclinal regions; he considers the small intrusions of basic rock as differentiates of such a granitoid source, and the process of differentiation, according to his opinion, occurs only at the very end of the granitoid source stage.

The concept that the source of acid granitoid magma usually starts in the period of maximum fold movements (incidentally, this is not a period of gradual orogenic consolidation) and is contradicted in many regions (Altay, the Far East, Kazakhstan, etc.) because even in the beginning and early

stages of large-scale geosynclinal development, extrusive activity with formation of thick acid lava and tuffs has occurred; these thick rocks are chemically similar to later granitoids and evidently are genetically related. Therefore, it is possible to assume that there is no universal type of magmatic development in geosynclinal regions, and the origin of granitoid magma at depth can take place during different stages of geosynclinal development.

The concept that the small intrusions of basic and intermediate rock and lamprophyres are formed as differentiates of granitoid magma is not generally accepted. Many investigators have indicated the impossibility of such a process and point to the formation of small intrusives from independent plutonic sources of diorite or basic magma. This work should be reflected in such a specialized work on dikes. The author's concept of the process of differentiation in plutonic granitoid magma, which he considers to begin at a late stage, together with formation of small intrusives, should be discussed. To some extent this may be correct for differentiation through crystallization, but it is incorrect for magmatic differentiation. This is true at least in every geosynclinal zone with multiphase occurrence of intrusives where the regular change of the rock composition from phase to phase with constant increase in acidity and alkalinity in later members of the series can be observed. For example, the change usually is from quartz diorite and granodiorite in early intrusives through the normal granite in batholithic intrusives to the alaskite, subalkalic or leucocratic granites in post-batholithic intrusives.

Chapter X (p. 213 to 219) is entitled "On A Method of Dike Study," investigating in detail the geologic study of dikes; the author forgets, however, one very important and absolutely necessary method in their study, i.e., mineralogic and geochemical analysis which is necessary to determine the relationship and differences between the dikes themselves and also between dikes and rocks of the major intrusives and extrusives. The combination of geologic, petrochemical, and geochemical methods of dike study, in which the last one is not completed by the study of accessory minerals only, but includes analysis of the entire complex of chemical elements of the rocks, is now the only safe way to reach an understanding of the genesis of dikes.

In the conclusion, the author repeats, in topical form, the fundamental concept of his work.

We conclude our critique of Kh. M. Abdullayev's book Dikes and Mineralization and stress once more that this is a very interesting and necessary work, especially with regard to the abundant new factual material, interpreting the dike problem from the different points of view. The book, however, contains several disputable and partly incorrect concepts, which are necessary to take into consideration in using the book. Besides there are many small errors and misprints in the book. Let us note the most important of them.

1. Porphyrites are often called "porphyries," for example, "diorite porphyry" on pp. 17, 53, 202, 205, and others, and on the contrary, porphyries are called "porphyrites" (granodioritoporphyrite on p. 35 and others).

Numerous serious arithmetic errors were permitted in the recalculation of analyses of rocks by the A.N. Zavaritskiy method. For example, the control recalculation of several analyses, which were included in Table 30, had shown the following: The numerical characteristic of an analysis for the sample No. 166 is written as: a = 11.8; c = 0.8; b = 17.1 and s = 70.3; our recalculation indicates that this should be: a = 12.3; c = 3.1; b = 11.4; and s = 73.2. The numerical characteristic of the analysis for the sample No. ch-40-Ab is written: a = 14.4; c = 0.0; b = 9.7; s = 75.9; but it should be, a = 14.3; c = 1.0; b = 9.2; s = 75.5. The Values of coefficient c shown in the same table in analyses are strikingly wrong for samples No. 20, 2910, 2908, Ch-37-Ab, 156, 154, and others. Correspondingly erroneous are the additional characteristics. Errors were made in the recalculation of chemical analyses in Table 10 (Analyses 39-a, 102), in which, incidentally, are contained not only additional, but also the main numerical characteristics; therefore, the titles in this table on pp. 92, 93, and 94 are incorrect.

3. Many errors are made in the transliteration of foreign literature.

4. Heuling (p. 180) gave descriptions of 144 mineral fields rather than 114.

5. Table 21 (p. 211) is called "Paragenetic scheme of mineralization . . . ." The scheme, of course, cannot be paragenetic.

6. Of course, the small errors do not deprive the book of its scientific value; however, it is deplorable that a work so well edited and generally necessary and interesting should contain such errors.

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SOME REMARKS ON V.V. BRONGULEYEV'S ARTICLE "THE BASIC FEATURES OF STRUCTURES AND DEVELOPMENT OF THE MIDDLE PALEOZOIC STAGE OF CENTRAL KARATAU."[1]

The regular geological surveys which are conducted in our country, especially in the east and the southeast, furnish many new and interesting materials every year. These materials are accumulated in territorial geologic offices and serve as the basis for the publications prepared for our people. However, only a part of the new geologic data can appear in print, because it is impossible to publish all the material collected by geologists.

V.V. Bronguleyev presents interesting scientific material in which he interprets differently the tectonic structures and stratigraphic units of the Upper Devonian and Lower Carboniferous. Unfortunately, after reading his work, even those geologists willing to accept his theory cannot be satisfied with the paleontoligic justification of his point of view, because of the haphazard manner of presentation of the article. Anyone can therefore cast doubt on the reliability of V.V. Bronguleyev's conclusions.

Our chief remarks can be given as follows:

1. The author's title reads "The Basic Features of Structures and the Development of the Middle Paleozoic Stage of Central Karatau," but the article is chiefly devoted to the study of Famennian and overlying deposits, not a word being said about the Silurian. If the author failed to include the Silurian in the Middle Paleozoic, this situation and the absence of the Lower Devonian should be explained.

2. The Etranian layers are in the meantime separated out, and if the author means to say they are not conformable, he is expected to explain the stratigraphy.

Etranian layers, as all other transitional strata, are recognized only in those places where it is difficult to set a boundary between the Famennian and the Turnean formations (the same marine conditions are preserved), and where a gradual transition to a marine environment occurred. But in places where there is no conformity between the layers, the transitional strata should be separated out. It is, however, quite difficult to do this here, as they are nonexistent.

In regard to the fauna dating the Etranian layers, let the one who determined them consider them so, according to the list of brachiopods given on page 27. However, it is possible to conclude that the rocks which contain them are related to Kassinian layers, i.e., far below the Turnean. (On line 20 from the top, on page 27, the genus Plicatifera ex gr. kassini Nal. is erroneously capitalized, in contradiction to the rules of Paleozoic nomenclature. The same occurs on page 26, line 9 from the bottom, and other places.)

3. Figure 10 on page 20 shows an unconformity in the Uyuk unit of the Lower Turnean over the squeezed and folded rocks of the Etranian stage. Therefore it appears that the Etranian lies transgressively on the older rocks, the Lower Turnean (Uyuk unit) sometimes being located right on the Lower Paleozoic (page 29, line 7 from the top); but V.V. Bronguleyev isolates the transition layers.

4. Rocks of the Kur-Perbay (D_3 fa^k) formation, correlated (by age) with the Famennian formation, also contain Productus (Plicatifera) cf. kassini Nal., the form which in Central Kazakhstan never appears below the Turnean formation.

The faunal descriptions of this unit, if carefully studied, are not accurate, because all forms are given with indexes: cf., nov. sp., ex gr., aff. (page 26, lines 8 and 9 from the bottom), i.e., with almost all indexes of Paleozoic nomenclature, showing only that certain forms are not yet fully known or have been badly preserved. There are even references (lines 1 and 2 from the bottom) that large Cyrtospirifer [?] were encountered in this formation but that they are still not correlated or identified.

5. The chief inaccuracy by the author is his incorrect description of paleontologic forms. V.V. Bronguleyev has made the excuse (page 18) that the overwhelming majority of fossil determinations were made by A.I. Zolkina, and comparatively few by R.Ye. Alekseyeva. However, in the appended lists of species there are many other types, and it is not indicated who identified them. For example, tabulate corals and rugose corals, and brachiopods of the Devonian and

[1] Izvestiya, Akademiya Nauk SSSR, Seriya Geologicheskoy, no. 2, 1957.

Carboniferous, i.e., such groups as at present a paleontologist can identify only very provisionally.

On the list on pages 19-20 certain surnames are written out fully (Solkina, Whidford, Grabau), while others are abbreviated (Rom., Murch., Khalf., Wen., Tien., Dav., and others). On the top of page 20, on the other hand, the surname "Solkina" is written out fully five times in a row. In paleontologic papers, according to the new instructions, at the first mention of a species or genus it is necessary to insert the full name of the author. V.V. Bronguleyev, however, never observes this rule. In many cases authors' surnames are given in abbreviated form: Vern., Na., Rom., Phill., Orb., and many others. Even though an author fully compiled the materials referred to, his surname must be written out fully; otherwise the author is unethical with respect to those authors whose surnames he abbreviates.

On page 23, in the description of fossils, the author permitted himself to make eight serious errors. In four cases species are capitalized (lines 4, 16, 26, and 27 from the bottom); in other instances "var." (variation) is written "vav." (lines 4 and 23 from the bottom). The name Koninck is given incorrectly (line 6 from the bottom); after the surname Hall there is an unnecessary period.

In conclusion it can be said that the ideas of V.V. Bronguleyev on the transgressions in Karatau are perhaps correct. His conclusions, however, are not persuasive enough because of the author's poor attention to the overall presentation of his work.

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A LETTER TO THE EDITOR

In answer to the remarks of the employee of the Kazakh Mining Metallurgical Institute, M.N. Koroleva, regarding data given by myself on paleontology in my article *The basic features of structures and development of the Middle Paleozoic stage of the Central Karatau* (News of the AN SSSR, Geological Series, no. 2, 1957) I would like to give the following explanation.

The problem on structures and history of development of the Karatau mountain range is undoubtedly very important but is extremely controversial. Concerning that problem, the new data collected by myself and related to stratigraphy and tectonics of this region required immediate interpretation in print. However, at the time when the article was published, the treatment of paleontologic material was only partly completed, and in my disposition only the preliminary determination of the fauna by A.I. Zolkina and R. Ye. Alekseyeva appeared. In this condition I should either not refer to the fauna altogether, or should give the list in the form in which the fossils were described in different handwritten geologic reports. Considering the necessity for a complex solution of the problem, I had to use the only, that is, the second solution. Unfortunately, in the handwritten reports which were available, there were errors and misprints, which managed to sneak into my article. Therefore, eventually, the series of species names were wrong and were written with capital letters, the family names of authors were not given uniformly, certain new genera were given without reference to the investigator who described them, etc. All remarks given by M.N. Koroleva regarding those errors are undoubtedly correct. M.N. Koroleva also illustrates the controversy in determining the age of the Kurpebay formation of the Famennian series which I recognized. The fact is, that within the list of fossils from this formation was mentioned *Plicatifera cf. kassini* Nal., (line 20 from the top, page 27), which was grouped on page 27 with the brachiopods; however, it is possible that the rocks including this form are Kassinian layers of the Lower Turnean. Also, there were several names wrongly written with capitals, which is against the rules of Paleozoic nomenclature. Unfortunately, only after the publication of my paper and more careful determination of this form and direct comparison of it with the original of D.V. Nalivkin was it established that this form has only a general resemblance to *Plicatifera kassini* Nal., and that it is a new species (*Plicatifera menneri* sp. n.). Therefore, the controversy which she mentioned can now be considered as suspended.

It is necessary to mention one more error found after publication. In the faunal description of the Kurusay unit of the Khatynkomal formation of the Famennian, Adolifia deflexa (Roem.) was mentioned between the other four. It has been proved that this form was determined by the presence of only two abdominal folds which were badly preserved. After additional collections of fossils and careful study of them, the presence of the above species in the unit was not confirmed.

M.N. Koroleva, stressing the importance of the above-mentioned small errors, thinks

that the reader may have doubts on the correctness of conclusions and in particular my opinion that in Karatau, the regional overthrust structures are absent within the Famennian deposits. This remark, however, could not be considered as a just one, because the classification of new stratigraphic schemes of Famennian deposits in the region was based initially not on the paleontologic data but on the study of structures, the thickness of the units, and the petrographic content of the layers of breccia dividing them, etc. Of course, we have permitted ourselves to make mistakes in determination which are really sorrowful, but at the present time they have been completely corrected. The information which is given in the final report of R. Ye. Alekseyeva and A.I. Sedyachenko (1957), leaving no doubt of the fact that the three previously separated formations of the Famennian do not represent the result of upthrust folding. Each of those formations is characterized by a special faunal complex; changing gradually their inner organization from bottom to top. Let me give some examples. In the lower units of the Khantagay formation, the following are widely distributed: Plicatifera meisteri (Peetz), Pl. tas-odyrica Nal., Cyrtospirifer murchisonianus (Kon.), C. verneuili (Murch), C. verneuili Gosseleti (Grab.), C. Calcaratus (Sow.) and Platyspirifer paronai (Martelli). The following are present in smaller number. Paryphorhynchus friaequalic (Goss.), Cyrtospirifer brodi (Wen.) and C. archiaci (Murch.). Then, in the upper layers of the same formation, in abundant numbers the camarotoechias, junnanellinos, junnanells, corals, and some new species of the genus Cyrtospirifer appear. In the Khatynkamal formation, the Schuchertella chemungensis (Conr.), Plicochonetes nanus (Vern.), Camarotoechia pleurodon (Phill.), Cam. pleurodon karatauensis Nal., Cyrtospirifer sulcifer (N.C.), C. pamiricus (Reed.), C. Semisbugensis sphaeroidea Nal. and E. aquilinus (Rom.) are widespread. In the upper part of the same formation species appear which are also characteristic of the Kurpebay formation (i.e., the third and uppermost units) of the Famennian formation: Plicatifera menneri sp. n. and Adolfia (?) deflexa Nal. (non Roem.).

New data corresponding in general to the findings of B.V. Povarkov (1957) from the West foothills of Tian-Shan and M.V. Martynova (1957) on Central Kazakhstan, do not permit the retention of an old stratigraphic classification for Famennian deposits of Karatau, but requires the revision of our concept on the thrust-folded structure of the Karatau Mountain Range.

M.N. Koroleva also blames me because I have not dealt in my work with the stratigraphy of Silurian and Lower Devonian deposits. It is necessary to say that these deposits are altogether absent in the region, and the Silurian beds were not considered especially because they form the next structural layer.

Finally, I am not in accord with the remarks on the transitional layers between the Turnean and Famennian, recognized by me. M.N. Koroleva considered it strange that from one point of view these layers are transitional, and from another they lie with sharp unconformity on underlying beds and are overlain unconformably by rocks of the Turnean.

I consider that the presence of local unconformities and the traces of erosion do not contradict the "transitional" concept, because it shows only the differential character of tectonic movement in the region during that period of time.

V.V. Bronguleyev February 12, 1958

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CHRONICLE

THE ALL-UNION INTER-DEPARTMENTAL CONFERENCE ON THE STUDY OF THE QUATERNARY PERIOD

The All-Union Inter-Departmental Conference, organized by the Geologic-Geographic Branch of the U.S.S.R. Academy of Sciences, Committee on the Study of the Quaternary Period, the Geological Institute, Institute of Geography of the U.S.S.R. Academy of Sciences and the Ministry of Geology and Natural Resources Conservation, took place in Moscow and Leningrad during the period of May 16 - June 2, 1956. Its aim was to reach conclusions on the study of the Quaternary system of the U.S.S.R. and also a series of approved solutions on the stratigraphy of Quaternary deposits and principles of their correlation.

This conference was preceded by a series of preliminary conferences with excursions to investigate separate problems of Quaternavy geology: In 1948, in Tashkent, on the problem of loess and neotectonics in Middle Asia; in 1953 and 1955 in North Byelorussia and Pribaltics, on the stratigraphy of Quaternary deposits: 1) in the north of the U.S.S.R., 2) in the central Russian plain and on general problems of stratigraphy; in 1955 in Kiev, on the problem of the origin of loess and loess-like rocks; in 1956 in Moscow, on the problem of the border between Tertiary and Quaternary systems.

The conferences in 1957 have been conducted, besides the plenary sessions, in nine parallel working sections: 1) the north and west Russian plain, 2) the central and southeast Russian plain, 3) Crimea, Caucasus, and Carpathia, 4) Kazakhstan and Central Asia, 5) Western Siberia and Ural, 6) Eastern Siberia with a subsection on the Far East, 7) On the history of Quaternary flora, and fauna, 8) on the history of fossil man, and 9) on general questions.

During the conference the following excursions were carried out: to the estuary of the Istra River in the Mozhaysk Region, for the study of glacial and interglacial deposits; in the region of the city of Vladimir for the study of geologic conditions of recently found Upper Paleolithic settlements on the left tributary of Klyaz'ma River, i.e., Sungir' River; following the Moscow-Leningrad line for t study of the classic glacial region in the environment of Leningrad: one to the wes of the town for the study of KAMES and t banded clays, another to the north, on th Karelian Isthmus, for the study of terrac and the section of Quaternary deposits in this region.

Special short guides for excursions an abstracts of almost all of the papers wer published especially for this conference. Altogether at the conference 220 papers w presented at the plenary sessions, and 1 in individual sections. More than 250 per took part in the discussions. More than persons, representing 144 organizations part in this conference; these organizatio were greatly concerned with the study of Quaternary period: several institutes and affiliates of the AN SSSR, and geologic a related offices of the Academy of Science of Union Republics, offices of Ministries Geology and Resource Conservation of th U.S.S.R., including the territorial geolog offices of the Ministry of Geology and Resources Conservation of the Kazakh SS the Ministry of the Petroleum Industry of the U.S.S.R., Hydro-Project, the univers and institutions.

In the conference work, the representa of the People's Democracies took part: Pr fessor E. Lityanu from Rumania, Zh. Bybylov from Bulgaria, Ya. Dylik from Poland, V. Ambrozh and K. Zhebera from Czechoslovakia, I. Hellert from the Germ Democratic Republic, M. Kretsoy from H gary, Pei Ven-chung and Liu Tung-shing from the Chinese People's Republic. The foreign guests presented nine papers.

Therefore, this conference was in fact congress of Quaternary specialists of the U.S.S.R. and demonstrated the great inte which the study of the Quaternary periods has among broad circles of scientific and dustrial workers.

The work of the separate sections was very fruitful, and was stimulated by the participation of representatives from local geologic offices and other local organizatio The amount of new and valuable factual material presented at the sections was ve

the plenary sessions papers of general est were read, but, unfortunately no ion was reached on basic problems se of a considerable division in opinion. resolutions in this part could be sum- zed as follows:

At the conference the following impor- stratigraphic problems were presented iscussed:

The name of the Quaternary period and wer boundary;

Stratigraphic subdivision of the Quater- system (general and local maps and ons and principles of their correlation);

On the first of these problems the con- ce concluded:

The majority of participants in the con- ce supported the proposition to accept rm "Anthropogene" jointly with the term ernary".

The majority of participants in the con- ce considered that there is enough rea- study the problem of lowering the ted boundary of the Quaternary (Anthro- e). However, before a special decision ached on this problem in the organiza- studying the Quaternary period, and e approval of concrete proposals pre- d to the scientific organizations by the -departmental stratigraphic committees, advisable to retain the present border.

With regard to the second problem at onference, there is no unified strati- ic column for the Quaternary deposits U.S.S.R.; also, there is a difference inion on the principles of its construc-

The necessity of dividing the Quaternary ropogene) period into three divisions, ing the lower boundary of the middle on on the basis of indications of the ning of maximum glaciation;

The desirability of preserving the ons of the Quaternary period, as they in four series: Lower, Middle, and r Pleistocene, and Holocene, as accepted e Ministry of Geology and the Conserva- of Natural Resources of the U.S.S.R.;

The expedience of using, as the units single stratigraphic column, the series e above-mentioned volume;

The possibility of using for these pur- not only series but also formations as subdivisions of the second order.

In the general resolution, which was accepted, the main trends in the study of the Quaternary period, the evaluation of contemporary conditions and their development, and a series of organizational proposals (the text of the resolution has been published and distributed among the participants in the conference and all interested organizations) were stated. Among the organizational conclusions is the decision to draw attention to the necessity for a quick solution of the following most important problems:

a) Determination of the lower boundary of the Quaternary period;

b) Establishment of a single stratigraphic column for the Quaternary deposits of the U.S.S.R.;

c) The revision of the principles of correlation of Quaternary deposits, especially marine and continental deposits.

Noting the general productivity of regional conferences on the study of the Quaternary period, in recent years, the said conference found it desirable to continue such meetings on a broad scale. In particular, for the coming years, the following conventions are proposed: In 1958 in Kazakhstan and Central Asia, in 1959 in the Urals and Western Siberia, in 1960 in Eastern Siberia.

The conference supported the proposition of the Section on Fossil Man to organize an international convention on the Paleolithic and its geologic age in the countries of Central and Eastern Europe.

The next All-Union Conference on the Study of the Quaternary period, with emphasis on stratigraphic consideration, has been scheduled for 1960.

To achieve greater accord on basic stratigraphic problems it is necessary, prior to the next All-Union Conference, to start a broad discussion on these problems in the press and at the scientific conventions.

V.I. Gromov and I.K. Ivanova

THE FIFTH CONGRESS OF THE INTERNATIONAL ASSOCIATION FOR THE STUDY OF THE QUATERNARY PERIOD

The Fifth Congress of the International Association for the Study of the Quaternary Period (INQUA) took place from September 2 to 7, 1957, in Madrid. About 280 representa-

tives from 32 countries were present at the conference: Austria, 4; England, 8; Argentine, 1; Belgium, 6; Hungary, 1; Ghana, 2; Holland, 15; Greece, 5; Denmark, 2; Israel, 4; Spain, 64; Italy, 31; Canada, 1, Morocco, 4; Mexico, 1; New Zealand, 1; Norway, 5; Poland, 8; Portugal, 2; Rumania, 4; U.S.S.R., 8; U.S.A., 19; Tunisia, 2; Turkey, 1; Paraguay, 1; Finland, 2; France, 55; The Federal Republic of Germany, 22; Czechoslovakia, 3; Switzerland, 3; South Africa, 1.

The Soviet delegation was represented by the following: Academician of the B.S.S.R. Academy of Science K. Lukashev, (Chief of the delegation); Academicians of the U.S.S.R. Academy of Sciences V.G. Bondarchuk, Ye.V. Shantser, and K.V. Nikiforova (GIN, U.S.S.R. Academy of Sciences); I.I. Krasnov (VSEGEY), I.S. Rozhkov (Yakutian Affiliate of the U.S.S.R. Academy of Sciences); K.K. Markov and A.K. Matveyev (MGU). All delegates lectured in different sections. The duties of the president of the Fifth Congress were discharged by Jose Albareda, as Secretary of the Chief Council for Scientific Investigation of Spain; Vice Presidents Francisco Ernandez Pacheco, Professor of Madrid University; Luis Pericot, Doscent of Barcelona University; Secretaries, Professor of Barcelona University Manuel Alia Medina and Luis Sole Sabaris.

At plenary meetings, the following papers were read:

1) Pericot (Spain) - The state and perspective of the study of the paleolithic in Spain; 2) P. Volschted (GFR) - The main divisions of the Pleistocene in Europe; 3) B. Galitskiy (Poland) - Stratigraphy of the lower Pleistocene in Poland; 4) P. Castani (France) - Tectonic deformation of the strombus zone in Tunisia; 5) J. Schuber and R. Raynal (Morocco) - Pluvial phases in the Early and Middle Quaternary Period in Morocco; 6) F. Ernandes Pacheco (Spain) - Glaciation of the Sierra de Keyja; 7) F. Ernandes Pacheco (Spain) - "Ranya Formation in the Pyrenean Peninsula"; 8) L. Sole Sabaris (Spain), G. Alimang (France) and K. Virguili (Spain) - Comparison of glacial formations of the southern and northern slopes of the Pyrenean Peninsula.

The main work of the congress was in sections, which were organized according to subject matter: 1) Astronomy and the Physics of the Earth (later united with the third section); 2) Soils, Climate, and Sedimentary Petrography; 3) Morphology; 4) Glaciology; 5) Hydrology and Limnology; 6) Paleontology; 7) Paleoanthropology (this section worked together with the eighth section on Paleoethnology); 9) Geochronology; 10) Paleoclimatology; 11) Regional Quaternary Geology; 12) The Stratigraphy of Sea Bottom Sedimen[ts].

Besides, the following committees were working at the conference: 1) On shorelines; 2) On the glossary for Quaternary geology; 3) On the nomenclature and correlation of the Pleistocene; 4) On modern tec[to]nics; 5) On geologic maps of the Pleistocene of Western Europe and 6) Symposium on radioactive carbon.

However, the distribution of papers acc[ord]ing to sections and committees was not always successful. The problems close to the theme of one section were often studied at different sections, and therefore it was hard to organize discussion of them. The translation of papers was also very badly organized: At the plenary meetings the papers (and not even all) were translated into Spanish, French, and English but in sections and committees, where the majori[ty] of papers were presented, no translation w[as] made in any language. Nevertheless, during the work of the congress many problems on Quaternary geology were sharply outlined; these problems are now the topic of attention of the Quaternary geologists of differen[t] countries; 1) Stratigraphic division of the Quaternary system and its lower boundary; 2) The geology of the paleolithic; 3) the ma[p] of Quaternary deposits; 4) The methods of determination of the absolute age of Quaternary deposits by radioactive carbon (C^{14}).

It is possible to outline the following major conclusions of the first problem. Th[e] stratigraphic subdivision of the Quaternary system is based, in all countries, chiefly on the paleoclimatic principle (Glacial, interglaciation, and interglacial periods). The data on pollen analysis is widely used, and pollen is used as the chief index of paleoclimate but not for paleostratigraphy. Paleostratigraphic methods, especially the fauna of mammals, are little applied in stratigraphic investigation, and some investigators do not agree on the paleostratigraphic importance of this fauna. As an example we can note that in the meetings of the paleontologic section, all papers on mammalian fauna, and they were quite numerous, were purely descriptive and morphological in character.

The paper of M. Van de Flerk (Holland) President of the Commission on Nomenclatur[e] and the Correlation of the Pleistocene, devoted to the summary of the symposium of this committee taking place in Holland just before the beginning of the congress was typical of the problems encountered. At this symposium an attempt was made to correlate the schemes for England, Holland, and North Germany, but this attempt was not successful because it was hard to corre-

e English "Krags" (?) with those in North rmany. An even greater discrepancy arose ring correlation of the diagram for North rmany and Netherland. In the Netherland gram at the bottom of the Quaternary stem after Guenz-Mindel interglaciation re are three cold glacial epochs separated the interglacials, which correspond only one Weiburn epoch in North Germany rrelated with the Guenz glaciation of the ps). Therefore, it appears that one formation in North Germany corresponds to three mations in Holland.

In what direction the attempt at stratiphic division of the Quaternary system, sed only on paleoclimatic and pollen data, l lead is evident from the fact that iburn "Krags" (?), on the basis of whose dy many investigators separated the soled Weiburn glaciacion, contain the torina Littorea fauna. This fauna is ieved to be characteristic of the Baltics the postglacial climatic optimum, but ny other molluscs which were found there d are now living in the North Sea. Theree, as is evident from the given example, paleoclimatic data alone, which are sed chiefly on pollen analysis, cannot be nsidered safe for stratigraphic purposes h as separation of glacial and interglacial ges. Broad biostratigraphy is necessary, d, first of all, the consideration of evolun of the mammal fauna. The exaggeration importance of local schemes, with the ailed separation of formations according pollen content, forced P. Beck (Switzerd) to deny the possibility of compiling a fied scheme even for the Alps.

It was found at the congress that in stern European and other countries, the stem accepted in 1932 at the second interional Conference (INQUA) for Division of Quaternary System into four series is applied at all or is applied by every ividual investigator according to his own nemes. In the stratigraphic scheme e.g., onesia, according to J. Koeningswals, the liglagan is included in the Pliocene, Getis the Lower Pleistocene, and Trinile in the ddle Pleistocene. But in the scheme offered D. Huyer, the Caliglagan is part of the wer Pleistocene, and Getis and Trinile - t of the Middle Pleistocene.

In the section of G. Cook on Africa, the wer Pleistocene is missing altogether d his classification appears as follows om the bottom up):

1. Lower Villafranc.
2. Upper Villafranc.
3. Lower Middle Pleistocene or Final Villafranc.
4. Middle Pleistocene.
5. Upper Pleistocene.
6. Holocene.

In the introduction to the resume of the symposium on the division of the Pleistocene, which took place in Holland, M. Van der Flerk writes that shortly before the convention, in answer to his letter, 22 absolutely different stratigraphic classifications of the Pleistocene were received from 22 countries.

The extreme use of local names even in the schemes for adjacent countries, e.g., Holland and Belgium, is also evident; the terminology, however, was different.

All of this, of course, makes correlation difficult and results in the complete absence of defined nomenclature and taxonomy, which in turn results negatively in the creation of a unified stratigraphic scheme. In this respect, the proposal of the members of the Soviet delegation (in the paper of V.I. Gromov, I.I. Krasnov, K.V. Nikiforova) to divide the Quaternary system into three series according to biostratigraphic principles, as is done for the other older systems, i.e., to separate series and formations according to appearance of new genera and species, were the most concrete and clear. Unfortunately, their proposition was not discussed widely enough, because it was presented at the meeting of the Committee on Nomenclature and Correlation to a very small audience. The President of this Committee, M. Van der Flerk, proposed to publish this scheme in one of the international journals in order to subject it to wide discussion.

The lower boundary of the Quaternary system was considerably lowered by the overwhelming majority of Western European and American investigators. Almost all of them set it under the deposits corresponding to Guenz and Danube glaciation, which previously have been considered Upper Pliocene, or under Villafranc deposits in all extraglacial regions. The volume of the Villafranc and its lower boundary remains uncertain; it is not known if the Villafranc corresponds to the entire Upper Pliocene or to part of it. This problem is very acute in the stratigraphy of Quaternary deposits, especially in the correlation of continental formations corresponding to the Villafranc with contemporary marine sediments. Do the deposits of the Villafranc correspond only to Upsheron or Akchagyl or even Kuyal'nik? This question was raised in the paper by K.V. Nikiforova and I.I. Alekseyeva. The following discussion

was culminated by a broad exchange of opinion.

Some data on the stratigraphy of Quaternary deposits according to the typical sections of several countries in Western Europe and North America is also worth attention. In North Germany, according to P. V. Woldschtat, instead of four glaciations, which are known up to the present time, five can now be counted; one lower one was discovered, under which the boundary of the Quaternary system is outlined. Therefore, the stratigraphic classification of Quaternary deposits of North Germany takes the following form (see Table). P. Woldschtat shows that two earlier cold epochs -- Weiburn and Brachtian -- are separated only on the basis of pollen; the deposits corresponding to these glaciations are very rare. It is not accidental that the names 'glaciation' are given by P. Woldschtat only to the three upper stages; the two lower-Weiburn and Brachtian he simply calls cold epochs.

P. Woldschtat also states in his paper, that the Varta stage previously included in the beginning of the Weichsel glaciation (W) is at present considered to be at the end of Zaal glaciation (RII), and therefore is correlative with our Moscow stage.

It is necessary to note that in Poland B. Galitskiy is inclined to consider the Varta stage to be related to the Riss (the end of Central Polish glaciation or the Warsaw first) but not as an independent glaciation. Besides, the Yaroslavl' glaciation is not yet accepted, and the Sandomir layer is considered Holocene. Stratigraphic division of the Quaternary deposits of Poland is also based entirely on paleoclimatic principles.

It is enlightening that Galitskiy has stated in his paper that the application of different criteria has been the main reason for division of opinions on the number of Quaternary glaciations. So, if based on the analysis of the mammalian fauna, he says, we will

Comparison with Alpian Glaciation			
W	Weikselian glaciation	Late	Stage Salpauselka Allerod-Interstage Stage Langeland Interstage
		Middle	Pomeranian Stage Interstage Brandenburg Stage Richsdorf Interstage
		Early	Stetin Stage before advance of glaciers
R-W	Eemian warm epoch		
R	Zaalian glaciation		Stage Wart (Zaal II) Interstadial Stage Drente (Zaal I)
M-R	Holstien warm		
M	Elster glaciation		
G-M	Kromer warm epoch		
G	Weiburn cold		
D-G	Tegel warm		
D	Brachtian cold		
N	Reveman (Pliocene)		

ɛpt one glaciation, and if based on paleo-ɔnic investigation, the number of glacia-ɔs will be greater; however, if only geo-ɔ data is taken into account, then there be many more glaciations. Hardly any-can accept this opinion.

n the scheme of division of the Quater-deposits of Morocco (according to hubert and R. Raynal, France) five ial periods are distinguished, the lowest nem, Mulut, corresponding to Danubian iation, is included by J. Shubert in the villafranc, and under it the boundary e Quaternary system is outlined. All remaining Villafranc J. Shubert sets r, including it in the Pliocene; he divides to two series Lower and Upper, as was pted throughout Western Europe, because Ponte, according to everybody, is in the er Miocene. Therefore, J. Shubert sets lower boundary of the Quaternary system in the Villafranc, which we consider incorrect because it contains a complex malian fauna.

n the stratigraphic column of Quaternary sits in Morocco Moustirian (Alterium) ure, in agreement with the majority of tern European scientists, is placed in Upper Pleistocene (Saltan, according to nubert); this does not coincide with the of Soviet investigators (see below).

n the stratigraphic scheme for North rica, according to R.F. Flint and . Wright (U.S.A.), the lower boundary e Quaternary system is outlined under oldest glaciation of Nebraska, which esponds to the Guentz, i.e., below Upper Pliocene; the stratigraphic column whole is kept in the same form in h it was published in the works of . Flint and G. Wright; only the position eparate stages of the last Wisconsin iation is outlined more accurately rding to radiocarbon data method for rmination of absolute age.

o, the Two-Creek interstage, which recently was placed between the Carey Mankato stages, according to C^{14} data an absolute age of 11,400 years and the kato 12,000-13,000 years before the ent. Therefore, the Two-Creek stage ounger than Mankato and is now set een the Mankato and the following younger, alled Walders stage.

vast majority of the glacial stages, d entirely on the data of pollen analysis, found by S. Venco in Italy. So, in the ıbian glaciation there were two stages e transgression in the Guentz 3, in the del 3. This scheme, presented by Venco at the congress, was subjected to sharp criticism even from those scientists, who themselves use paleoclimatic data, in particular pollen analysis as a basis for subdivision. A clearer scheme of division of the Quaternary of Italy was presented by A. Blanc. He distinguishes five glaciations, starting with the Danubian, under which he outlines the lower boundary of the Quater-navy system (the names of glaciations are local). In the Riss he distinguishes two stages, corresponding to the maximum of Dnepre glaciation, or correspondingly, the Moscow stage in the U.S.S.R. or Wart stage in North Germany. In Wurm, A. Blanc recognizes three stages, which correspond to the conventional ones in Western Europe.

A considerable division in opinion of Soviet and Western European scientists on the geologic dating of paleolithic remnants, particularly on the age of Mustier and initial cultural stages of the Upper Paleolithic was exposed at the congress.

V.I. Gromova and Ye.V. Shantser developed and justified the differing points of view on the pre-Riss and Riss age of the Mustier, which prevails at present between the Soviet scientists, in their paper The Geological age of the Paleolithic in the U.S.S.R. The paper provoked a series of critical remarks, but the discussions had proven that certain facts discovered in Western Europe give an opportunity for agreement in the future. Particularly interesting in this direction is the paper of A. Blanc (Italy) The problems on the chronology of the paleolithic of Lacium, in which he came to the same conclusion on the age of the pre-Riss and Riss of the early Mustier.

In the paper of G. Mueller-Beck (Switzerland) The stratigraphic subdivision of the European Paleolithic the conventional Western Europe scheme was basically developed. However, in the paper and especially in discussions of this paper, the author supports the conception of the asynchroneity of cultural stages in different regions of the Old World, in particular, on their earlier appearance in the east, and also further migration to the west. These very disputable conceptions are, however, worthy of attention, because certain asynchroneity of similar remnants of the paleolithic in different parts of Europe has recently received confirmation by a series of facts.

Therefore, undoubtedly, these three papers have posed several complex problems before the participants in the conference, which can be solved only through mutual effort of the scientists of all Europe.

Other papers dealt chiefly with more local but at the same time very interesting

problems on archaeology and dating of the paleolithic. So, in the paper of P. Bieberson (France) New data on 'gravel culture' in Cis-Atlantic part of Morocco the author demonstrates the ancient type of stone weapons in the layers synchronous with the Villafranc and the Calabrium, i.e., at the very beginning of the Pleistocene or the end of Pliocene time. In other papers of P. Bieberson, e.g., Discovery of bòne products in shell-ashell culture of the Cis-Atlantic part of Morocco he shows very convincing traces of bone treatment and probably also that of wood as early as early Paleolithic time.

It is necessary to note that the evident difference in approach to archaeologic dating here and in Western Europe, has a certain importance in determination of the geologic age of the Paleolithic. For example, we consider the Mustier culture and Levalois culture as very close, but in the west they are considered sharply different. Or, for example, the settlement containing very nicely-wrought quartz arrowheads evidently of "Scythian" type, is related in Western Europe to the Developed Madlen, which could be concluded after a visit to archeologic museums in Madrid and Valencia. However, for more exact geologic dating of the paleolithic, it is necessary for mutual revision of archeologic material.

In 1953, at the 4th Congress of INQUA in Rome, Professor R.F. Flint (U.S.A.) proposed to compile a small-scale map of Quaternary deposits of Western Europe. A special committee was organized for this purpose. Its president is Professor P. Wollstet (FGR).

It was also decided to compile this map at a scale of 1:4,000,000 or 1:3,000,000 in black. During the four years the committee has made only a preliminary map at a scale of 1:3,000,000 for North Germany, Belgium, Denmark and Southern Sweden. In this map only 20 conventional symbols were used, of which those representing the genetic type of sediments prevail, as well as several geomorphologic and paleogeographic symbols. Stratigraphic subdivision of deposits has been given very schematically.

Only the geologists of the German Federal Republic, Holland and Denmark have taken part in compiling this tentative map. The Committee has not yet received any material from other countries of Western Europe. Critical remarks on this tentative map also have not been received.

At the 5th Congress in Madrid, the first meeting of the committee on the map under the presidency of Prof. Wollstet took place. He also reported that because the Soviet Union has resumed its activity in INQUA, it is possible now to broaden the aims of the committee, and proposed to compile the map of Quaternary deposits for all Europe, including the U.S.S.R. and the countries of the People's Democracies. The committee also concluded that it is better to abolish the unicolor variant of the map and that it is necessary to work out a legend for plotting a multicolor map. This proposition was made after the paper presented by I.I. Krasnov, representative of the Soviet delegation was presented, containing several multicolored legends and maps of Quaternary deposits of the European part of the U.S.S.R. and adjacent countries at a scale of 1:2,500,000 and sheet 19-20 of the International Map of Quaternary deposits of Europe at a scale of 1:1,500,000. It was decided to work out a multicolored legend for the maps of Quaternary deposits in Europe at a scale of 1:4,000,000 and send it to all members of the committee for discussion; in the spring of 1958, at the special meeting of the committee, the legend should be ratified.

The proposal of the Soviet delegation on widening the functions of the committee on the map of Europe and renaming it the committee for an International Quaternary Map was carried out at the plenary session where the majority decided to establish a new committee for the International Quaternary Map, which includes: delegates from the U.S.A., Prof. G.M. Richmond (President), and delegates from the U.S.S.R., K.I. Lukashev and I.I. Krasnov.

The symposium on the radiocarbon method for the determination of the absolute age of Quaternary deposits has shown that the leading country in the development of this method remains the U.S.A. However, major work on the improvement and practical application of this method is also being carried out in several countries of Western Europe. Recently, in the west, with the aid of the radiocarbon method, the age of layers of our era up to 50,000 years old have been determined. Thus, according to de Frise, the age of layers corresponding to Wurm I, Wurm II, and Wurm III in Holland is determined to correspond to 44,000, 33,000, and 20,000 years before the present.

During the sessions of the congress, several excursions were carried out. In the excursions to the Pyrenes before the beginning of the congress session, the Soviet delegation did not participate. In excursions to the Sierra Guadarrama and Sierra Gredos the participants received a general impression of the relief and geomorphology of these territories and on the traces of glaciation to

hich they were subjected.

In the excursion to the Mediterranean Sea nd on Majorca Island the greatest interest as in the inspection of the marine Tirrenian rmation.

It is possible to observe two layers of irrenian beaches at a height of +20 m. and 5 to 6 m., and one Early Holocene (Flanrian) at +2 m. The highest, 20 m. level, ntains a rich fauna, in which the comete absence of typical tirrena forms is aracteristic. Its age is now considered as irrena 1.

Level + 4-6 m. is related by age to Tirna II. The deposits of this terrace are leontologically rich. They contain *Strombus bonis*, *Conus testudinarius*, *Murex*, *Cerithm* and many *Cardium* and *Pectunculus*. The west terrace, + 2 m., is Flandrian in age.

Together with the marine deposits on the land of Majorca and on the Spanish shore the Mediterranean, the dune deposits lated to terrenean formations were also und.

At the northwestern shore of Majorca at e Harbor of Soller, the delegates observed e well-exposed outcrops of Triassic and wer Jurassic rocks, represented by crysllized limestones, which overlie the horintal Lower Miocene (Burdigal) deposits. n the shore cliffs it is easy to see the recent faults with their zones of mylonitization and mirror-like slippage.

At the end of the work of the congress, at the plenary session propositions on general problems of INQUA suggested by the delegates, Soviet delegates included, were also discussed.

According to the proposition of K.I. Lukashev (U.S.S.R.) special subcommittees on the lower boundary of the Quaternary system were organized and on the study of the Holocene were combined with committees on nomenclature and correlation; the committees on the world map, absolute age, and lithology and genesis of Quaternary deposits. Within the committee on shorelines, the subcommittee on the study of sea bottom sediments was organized.

All committees were reinforced by Soviet representatives, as the President of the Committee on Lithology and Genesis, Academician of the Byelorussian Academy of Sciences K.I. Lukashev was elected. At the meeting of the leaders of delegations from all countries the question on the location of the next, sixth, congress of INQUA, which should take place in 1961, was discussed. The majority, in secret balloting, decided to convoke the sixth congress of INQUA in Warsaw.

K.V. Nikiforova   Ye. Shantser